MACHINERY AND MATERIALS

Planning, Providing and Caring for Plant Equipment—Purchasing, Storing and Handling Materials

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Being the Fourth Unit of a Course in Modern Production Methods

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BUSINESS TRAINING CORPORATION
NEW YORK CITY

HARVARD UNIVERSITY
DIVISION OF EDUCATION
BUREAU OF VOCATIONAL GUIDANCE

Course in Modern Production Methods

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The text of the Course is issued in six units as follows:

I. Teamwork
II. Handling Men
III. Organization
IV. Machinery and Materials
V. Production Records
VI. Management

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Labor-Aiding Machinery

THERE was a time when thirty-two days of labor were required to make a linen sheet, and a grid-iron cost from five to twelve days of expert hand labor. Today we turn out these and other products by the hour—in some cases, by the minute. And the thing that has brought the difference is MACHINERY.

"Labor-saving machinery should be called labor-making or labor-assisting machinery," said Carrol D. Wright, of the United States Department of Labor, commenting on the changes which have come in production.

Compare industrial activities and output today with those of a hundred or fifty years ago, and you will see that this is true. The introduction of machinery, far from doing away with human workers, has had the opposite effect of increasing them. More men are making shoes by machinery today than were making shoes in the old days when the manufacturer was a cobbler pegging away with hand tools. More workers are employed in textile industries today than was ever the case under the domestic system of household spinning and weaving. And so with countless other industries.

Machinery cheapens production and thus brings the products of the factory within reach of more people. And it cheapens production because it increases the rate of production. A man can turn out more work with equipment than by working with his bare hands. Therein lies the reason for the use of machinery. Therein lies the importance of knowing the ins and outs of mechanical equipment. Because of machinery industry has become more productive, less burdensome, more profitable both to employer and employee.

I

Recent Industrial Development

A FEW months ago a steel torpedo boat destroyer was built and launched in seventeen days. In another American shipyard a 12,000-ton cargo ship was completed in a little over three weeks. At the same time eight or ten American munition factories were turning out millions of rifle cartridges daily, all to very accurate dimensions and all interchangeable for use in millions of rifles. Airplane motors, truck motors, and other machines were being made in enormous quantities, part in one factory and part in another, and, in many cases, assembled in still a third factory.

The Application of Machinery

The carefully-planned cooperation which makes possible this big-scale, high-speed production, is the result of the application of machinery and of mechanical principles to the work of production. American factories have been able to rise to the war emergency be-

cause they have at every possible place made use of steam, electric, or gasolene power; and because they have put into effect at every possible step of their operation those three principles which have been pointed out as the basis of big-scale production, namely: *standardization, specialization,* and *the elimination of waste.*

The application of these principles is not something that happened overnight, however. Unit I has discussed the slow development of the factory, from the primitive system of the early handicraft worker to the highly organized methods of the modern industrial plant. With the coming of machinery in the latter part of the eighteenth century, this development was quickened, though even in England where the industrial revolution started, the general replacement of hand-workers by machine-workers required many years.

In the United States, the effect of the great inventions was even slower in making itself felt. One reason for this was the fact that the industry of the country was largely agricultural, the population small and scattered, and so the spur to industrial production was not so great as was the case in the old and settled lands of Europe. A few small textile mills, paper mills, and other primitive industries were early established in New England and

near the ports and along the waterways of other Atlantic states, but the energies of the people of the United States for the first seventy years of their existence as a nation were largely spent in opening up and settling the West, and in trading and agriculture rather than in manufacture. Of the manufactured goods needed, a large part of them were brought in from Europe; and perhaps an even larger part were home-made handicraft products.

Industrial Awakening of the United States

The industrial awakening of the United States came with the Civil War, which broke out in 1861. The war called for a sudden increase in factory production of many kinds of goods, just as was the case in the United States with the outbreak of the great war with Germany in later years. And with the ending of the war in 1865, the United States entered upon a period of industrial development which has continued with ever-increasing strides from that year to this.

In 1860, all the factories of the United States taken together represented a total invested capital of about one billion dollars. Today a single American industrial corporation has a billion dollars capital. The annual output of all manufacturing concerns in the

United States in 1860 was two billion dollars' worth of goods, including everything from locomotives and ships down to needles and pins. By 1890 capitalization had increased six-fold, and the anual output was more than nine billion dollars' worth. By 1910 capitalization was close to twenty billions and annual output was nearly twenty-one billions. No statistics are available as to the present capitalization and output of American industry (the next national census is scheduled for 1920) but it is safe to say that the growth during the past ten years has far outdistanced that of any previous period. The United States stands today in the very forefront of the industrial nations, being the heaviest producer of a number of leading products such as iron and steel goods, automobiles, rubber goods, leather goods, petroleum products. It has become the chief export country of the world, and in South America, China, and many parts of Europe, American typewriters, American motor cars, American photographic goods, American locomotives, American steel, American harvesting machines, American kerosene are now almost as well known and as generally used as they are in their home land.

The fact that American industry is largely the growth of the past fifty years has saved

it from many of the set traditions, prejudices, and other handicaps of older industrial lands. It is less moss-backed, more friendly to improvements and innovations of various kinds, more adaptable to new developments in machinery and methods. Thus, it is in the United States that the principles of standardization, specialization, and elimination of waste have found their greatest application. The Ford, the Ingersoll, the Kodak—each of which is the result of the application of those three principles—are distinctly American products. You cannot parallel them in any outside land. And they are only three examples of hundreds of standardized American products which might be named.

American Industry Forward-looking

It was America's experienced knowledge of the principles and methods of big-scale production that made it possible for the nation so rapidly to readjust its production to war demands. Take shipbuilding, for example. Nothing in the history of industry is more dramatic and thrilling than the way in which American workmen with American machines turned to the shipbuilding trades, and within a year had pushed the United States into the very forefront of the nations in the production of ships. Here is a practically new in-

dustry which will not die down after the war, but which we may expect to continue to employ thousands of workmen and turn out a vast tonnage every year, in peace times as well as in war times.

The New Industrial Era

In fact, it is safe to say that peace will make even greater demands upon the producers of the world—and of America in particular—than war has made. Its demands will be more diversified, and for that very reason a larger volume of production will be called for. There is every reason to believe that the era following the war with Germany will duplicate in large measure the industrial expansion which followed the American Civil War—only, in enormously increased extent. Just as the population of the nation and of the world are greater than they were then, and the needs growing out of this war are greater, so will the impetus to industry and the manufacturing activity in every line be correspondingly greater.

In meeting this increased need, the United States and the other industrial nations will make increased use of machinery. It is not only that the shortage of human workers must be made up for by giving over additional tasks to machines, but that the human workers are more needed in the brain-work

of production. Foremen and managers in the new industrial era will be more than ever masters of machinery, knowing how to use its labor-saving and labor-aiding principles to insure greater accuracy and rightness of product as well as to speed up output.

Not only the actual machines themselves, but the combination of machines in groups, their arrangement to attain greater efficiency of movement of work, and the placing and planning of the plant itself so as to secure the greatest possible rate of output—these are subjects in which the production man in the new era must be thoroughly versed. He must know his equipment, how to adapt it most closely to the needs of his production, how to apply to it the principles which reduce costs and increase output.

Why the Foreman Should Know Plant Organization

Such knowledge is not for managers alone. Of course it is they and the other higher executives who are usually responsible for the choice of plant location and layout and for the selection and arrangement of machinery. But the foreman also must know the "why" and the "how" of these things if he is to be most successful in his work. He cannot have a firm grasp upon operating methods unless he knows the basic principles governing the placing, planning,

and equipping of the plant. All-round knowledge is essential to capable leadership and swift advancement in executive work. It is just as important for the foreman to know how the plant is organized and built up as it is for him to know how the factory team is formed.

Not only will this broader knowledge of the mechanical organization help the foreman to a better grasp of his work, but it will make him more appreciative of the difficulties and the problems which the management has to face. It will make him more understanding—less critical—a better interpreter of the business to the men under him. In many a shop where appliances and routine methods seem old-fashioned, the men are inclined to criticize; they may say that the management doesn't know its business; whereas the truth may be that the location of the plant, the general nature of its work, or some other factor makes the methods now in use there the most productive and therefore the most efficient under the circumstances.

It is these questions of planning, selecting, organizing, and using equipment and materials that form the subject-matter of this fourth Unit. Obviously it is impossible to discuss the technique of every distinct line of industry. To do that would require an en-

cyclopedia of several hundred such text-books. What the Unit will do is to present the general principles which apply to industrial plants of every nature—the basic rules which govern plant equipment and the handling of materials in factory production. Your job—and an interesting and highly profitable job it is—will be to take these principles and see how they apply in a definite, concrete way to your own plant and to your particular work in that plant.

II

Types of Manufacturing

THE production plant or machine must be viewed in the light of the kind of work which it performs. A necessary first step to the study of the equipment of manufacturing, therefore, is a study of the types of manufacturing.

There are various ways of classifying manufacturing. We may classify it:

1. According to the type of goods which it produces.
2. According to whether its operations are handicraft or machine work.
3. According to the nature of its processes—whether they are chemical or physical.
4. According to the layout of its processes—whether they can be carried along in parallel order or must follow one another in regular sequence.
5. According to the nature of the business carried on—whether the product is manufactured to fill advance orders already secured from customers, or is made to be carried in stock.

Each of these classifications represents a different way of looking at the factory, and ordinarily a single factory would occupy

a distinct grouping under each of these five headings. However, let us take the headings in order and consider them separately. Perhaps the most common and easily-recognized classification is that which subdivides industry into various groups on the basis of what it produces. Thus, we may distinguish general types of manufacturing activities producing nine groups of products, as follow:

Classification According to Product

1. Food and kindred products.
2. Textiles.
3. Iron and steel and other metal products.
4. Leather and its products.
5. Rubber and its products.
6. Chemicals and allied products.
7. Clay, Glass, and Stone products.
8. Vehicles.
9. Timber and kindred products.

Examples of each of these groups are familiar. Meat-packing plants and canneries are typical of Group 1. Cotton, woolen, and silk mills, and clothing factories are representatives of Group 2. Foundries, machine shops, watch factories, and gun works come in Group 3. Shoe factories are in Group 4, tire factories in Group 5, paint and soap factories in Group 6, glass works and brick kilns in Group 7, automobile factories in Group 8, and sawmills and furniture factories in Group 9. It is obvious that this kind of classification

might be carried to any degree of itemization. Thus, instead of nine groupings, we might subdivide and extend the list to make fifty or a hundred.

It takes only a slight acquaintance with the groups that have been listed to see that they vary widely in their manufacturing methods, and right at once we recognize that classification according to product gives only a superficial analysis of the types of manufacturing. We want to know more than what a type of manufacturing produces. We want to know how the manufacturing itself is carried on.

Thus we find that in some manufacturing, hand work and constant attention to the production process are necessary. In other manufacturing, the machinery is almost automatic in its action; only minor supervision is necessary. From this we get a second way of classifying manufacturing. We may classify it as:

1. Hand Work.
2. Machine Work.

Hand Labor and Machine Production

The meat-packing industries, for example, make use of a large amount of hand labor. The carcass is placed upon a conveyor as soon as it is killed, if not before, and it travels along from one workman to another, each man performing his specialized function

in transforming the carcass into its numerous products—hide, fertilizer, food, soap, and so on. The process is one of breaking up a raw material, the meat carcass, into its various parts and making them ready for use. Altogether it is an industry in which hand-work predominates, though machinery is used to some extent.

In canning fruits, vegetables, fish and other products, mechanical appliances largely take the place of human skill; and the cans are filled, sealed, labeled, and sorted, largely by machine methods.

An even more striking example of the predominance of machinery is found in the manufacture of certain textiles. In the spinning and weaving of cotton and wool in modern mills, for example, the machinery is largely automatic or semi-automatic, so that one operative is able to attend to a number of machines. Automatic conveyors carry the material from one machine to another, and many of the processes are mechanically regulated. Yet this is not the case with every kind of industry coming under the heading "textiles." In the manufacture of clothing, for example, hand labor is largely used; as is the case with certain types of rug, lace, and silk manufacture.

In the same way, one can go through the

entire list of manufacturing industries and classify their processes according as they make use of machines or of hand labor. In a majority of the cases, both hand and machine methods are used; some of the operations being performed by automatic machinery, others by hand, and both kinds of manufacturing being necessary to the successful production of output. This is the case in much machine-shop manufacturing. Screws and bolts and nuts may be made by automatic machines, whereas skilled labor is required to put the parts together in the final assembly of the finished product.

Chemical or Physical

But manufacturing may be classified not only according to product, not only according to the character of its work, but also according to the nature of its processes. All manufacturing takes place through either

1. Chemical changes in material, or
2. Physical changes in material.

There is no chemical change in cotton when it is spun into threads, when these threads are woven into cloth, or when the cloth is cut up and sewed into clothing. The manufacturing here is purely physical. But in making cotton into explosives, the manufacturing consists of bringing it into contact with

certain acids which by chemical action change the composition of the cotton to create a new substance. The manufacturing here is by chemical rather than physical change.

The manufacturing in the meat-packing plant is both physical and chemical. Cutting up the carcass is physical. It simply changes the physical form of the material, divides it up into various parts. But curing a ham or preparing a side of bacon involves chemical changes in the nature of the meat caused by the salting, smoking, and curing process.

Many other industries make use of both chemical and physical manufacturing. In the iron and steel industry, for example, the manufacture of iron and steel may be classed as largely chemical. The ore, coal, and other elements are mixed together under great heat, and the result of this mixture is iron. The mixing of iron with carbon, manganese, or other appropriate elements under suitable conditions, at high heat, results in steel. Both of these processes are chemical. But in making the iron into castings, in rolling the steel into rails, or in fabricating the steel into a locomotive, the manufacturing process is physical. It consists simply of changing the form of the material, and shaping it into a given design.

The prime difference between chemical

and physical manufacturing is that the first changes the nature of the material whereas the latter merely changes the form. The first changes rough ore into pure iron; the latter changes molten iron into castings, or turns a block of steel into a finely bored and smoothly polished engine cylinder. You can classify your own factory's manufacturing processes according as they are chemical or physical.

The fourth classification of manufacturing is based upon the order of processes. The manufacturing may consist of

1. Parallel production of various parts, or
2. Sequential production, in which each process must follow in a certain order.

Parallel Production

In the automobile factory, parallel production is common. Work upon various parts of the automobile is going on at the same time. One department or group of men will be busy making wheels while another department will be turning out the car bodies, another getting ready the upholstery and various furnishings. All of these manufacturing processes are going on simultaneously, and are paralleling one another; as a result, when the car comes to its final assembly each part is ready and can rapidly be fitted into its place.

In assembling also there are various proc-

esses going ahead at the same time. One department may assemble the parts of the engine, while another is equipping the dash and the steering column, and still a third department may be busy attaching the transmission to the frame.

Each department can work independently up to a certain point. There comes a time, however, when the various assembled parts must be combined into an automobile. Then the assembling must proceed according to a fixed order, one process preceding another. The frame must be in position before the engine can be placed upon it, and the engine must be in place before the radiator can be attached; and so with other parts. Every step of the manufacturing here must follow a certain sequence or order.

Sequential Production

Examples of sequential manufacturing may be found in practically all types of factories. In the canning factory, the soup must be prepared before it can be put into the cans, the cans must be filled before they can be sealed, they should be sealed before the labels are pasted on. For another example, take the case of a machine shop which manufactures screws. A long bar of steel is put into the machine. First it is turned to size, and then the thread is put in; the thread could not be made first, because

then it would be shaved off when the bar was turned. After the screw is shaped and threaded the machine can perform its last operation—namely, slot the head. This sequence of operations is necessary; no two of them could take place on the same screw at the same time. One process must precede the other in fixed order.

It is seldom possible to link up all operations in a single machine, so that the work is fed in as raw material at one end and comes out as finished product at the other. This is accomplished to a degree in modern paper-making machines. In operating a paper machine there must be a continual flow of the paper pulp, and as soon as the web of paper is formed it must travel through the entire length of the machine without variation of speed. The wet paper will not permit any stretching. If the paper breaks or the supply of pulp is suddenly interrupted, the machine must be stopped and the whole web sent through again.

A break-down or delay in any one process in a chain of sequential operation interrupts the whole production. Just as an accident at any part of the paper machine stops the entire process of manufacturing, so an accident at any step of the assembly of an automobile or other machine stops the entire process of as-

sembling the machine. This source of waste and expense in sequential manufacturing is guarded against by careful planning of the work to render a break-down less possible, and by keeping some reserve stocks of material in process so that should a break-down occur the men at the operations following the one which is broken down may turn to these reserves and spend their time profitably.

Manufacturing may be further classified according as it is

1. Manufacturing to order, or
2. Manufacturing to stock.

The two terms are self-descriptive. An automobile company which manufactures a certain number of motor trucks to fill a customer's order, is manufacturing to order. It has its product placed, its goods contracted for, before it begins manufacturing. On the other hand, when the company is turning out motor cars with a view to placing them in stock for sale to such customers as may be secured, it is manufacturing for stock.

Manufacturing to Order

Manufacturing to order is usually a more expensive undertaking than manufacturing for stock, since in the former case the product must be made to suit a particular customer and must usually follow his special design and conform to special requirements. Large and costly

products, such as ships, locomotives, heavy electrical machinery, and the like, are usually manufactured to order. At the same time, there are many small products, such as shoes, cigars, clothing, which are manufactured to the order of individual customers.

One usually understands "manufacturing to order" to mean in accordance with orders or directions affecting the design, etc. Manufacturing a stock design on order is the same as making to stock. Only a small amount of goods manufactured to stock actually goes into the stock rooms of the maker.

Most make-to-order business involves special problems. In the usual case, the manufacturing must be adapted to meet special requirements. When this is so—when a product must be made to suit the special design of a customer—a number of things must be done before actual operations can begin. Often drawings must be made, patterns supplied, bills of material drawn up, and requisitions issued for the purchase of any special materials required. In some cases, these preliminaries may require a number of days or even weeks.

After the material has been obtained, or while it is being obtained, the necessary shop equipment must be scheduled so as to insure that the special order will be put through the

factory with the least interruption of other work in process and on hand. If the factory is occupied to capacity, it may be necessary for a given order to wait for a place on the manufacturing schedule. If a plant holds itself in readiness to take on such orders for prompt execution, obviously it must increase its price to take care of excess equipment.

To safeguard against possible delays, it is customary with some concerns to give an order to "make and hold" the special production desired. From the manufacturer's point of view this is not the most desirable business. The purchaser may find it to his advantage later to cancel such business which has been ordered far in advance, and this may involve troublesome problems. Delivery of an order should ordinarily be made as soon after completion as it can be shipped.

Manufacturing for Stock

In manufacturing for stock, big-scale standardized production is possible. The factory adopts a design for its product or products, determines the grade and quantity which it will turn out, and then is able to organize its working force and equipment with a view to handling this production most efficiently. It is the story of the Ford, the Ingersoll, and the Kodak all over again. If the Ford factory undertook to build cars to the special order

of this, that and the other customer, its output would be considerably reduced and its selling price would have to be raised. It is because Fords are made according to the standardized design of Mr. Ford's engineers, and not according to the customer's individual design, that the factory is able to turn them out so rapidly and at such low prices. It is the same way with a suit of clothes or a pair of shoes. Ready-made clothes and ready-made shoes are simply clothes and shoes that have been made to stock. The tailor and the shoemaker charge more for their made-to-order products because in their case the clothes and the shoes must be measured, cut, and put together to suit individual customers.

In manufacturing for stock the manufacturer assumes a risk. Ordinarily he must manufacture first and get his orders afterward. Some factories in recent years have been fortunate enough to run at continuous uniform rates without storing their product, by requiring their selling agents to agree to take a certain allotment or quota of the product for delivery when it can be turned out. This plan has been used by many of the automobile factories. Frequently the agent for one of these factories will have received orders for his entire quota of cars before the cars are delivered from the factory. Usually,

however, the manufacturer is not able to organize his selling on this basis, but must turn out goods in the quantity which his sales department estimates can be sold with profit, and must store part of this output during the dull season to tide over the heavy selling period of fall and spring.

Sometimes it appears that the cost of carrying goods in storage to meet the sales demand of a brisk period is more expensive than to fit the factory schedule to this rising and falling demand by operating full-time for a certain number of months and half-time or even less on other months. This is a matter that requires careful consideration from the executives in charge of production, since intermittent operation has a very direct effect upon the efficiency of workmen.

Continuous Employment Helps Efficiency

In one New England factory, the efficiency of labor was so increased by the promise of continuous employment that it was possible to produce in one 10-hour shift what had formerly required two 12-hour shifts under the intermittent plan of operation. From the standpoint of maintaining a permanent skilled labor supply, the policy of continuous operation is highly desirable.

If the goods are bulky or very expensive,

or are otherwise difficult to store, the storage problem may become a serious one. Storage may demand space that can ill be afforded, owing to the demand for manufacturing room. This may be overcome in some instances by carrying a stock in district warehouses, or on consignment with jobbers and dealers. That is, the goods may be made and shipped to jobbers and dealers to be paid for when they have sold them, or to be paid for after a longer time than is allowed on regular sales.

In some instances, there is a diversity factor that affects sales. Due to climate or similar conditions, goods may sell in one part of the country when they will not sell in another. By developing this factor to its greatest possible extent, and by cultivating an export trade, it may be possible to bring operation up to a uniform condition without involving the carrying of a large stock.

The final answer to the question whether to store or to operate intermittently is determined by weighing the cost of storage against the cost of obtaining and training new labor whenever it is necessary to build up the labor force. On the one hand is the cost of carrying the material in storage, interest on the money invested in goods, insurance of the goods in storage, the cost of handling and of

possible deterioration or spoilage as a result of storage. On the other hand, there is the cost of obtaining new labor, of training this labor, loss of output during the period of learning, increased consumption of tools, materials, and supplies used by labor, and increased spoilage of material during the period of training. From the standpoint of the manufacturing department alone, continuous uniform operation is very much to be desired.

Some concerns manufacture both for stock and to order, and find that this helps to stabilize their operation. Take the case of the General Electric Company, for example. In its plants it is constantly making dynamos, motors, and other electrical goods in standard sizes and according to standard patterns. This output goes into stock from which sales are made. But frequently the company receives an order for an electrical machine of a special design. A new water power company may require hydro-electric generators for a special installation; or an electric power equipment may be wanted for a transatlantic liner; or a railroad company may require electric equipment of its own design. All these are special orders, and must receive special treatment. Practically all of the large

machinery factories manufacture both for stock and to order.

How the Groupings Overlap

It is clear that the five classifications of manufacturing discussed in this chapter represent various standards of grouping. Each classification has a different basis, and as a result the classifications overlap. Practically any example of manufacturing would qualify in some group under each of the classifications named.

Take the case of a furniture factory, as an example. Its manufacturing is classified: (1) under the heading "Timber and its products," since the furniture is of wood. (2) Assuming that it is a large standardized plant, much of its production will be by machine, though some of the processes (such as finishing, painting, and decorating) may be largely handicraft. Here it would be necessary to analyze the manufacturing into the various processes, and classify each according as it requires hand work or machine work. (3) The manufacturing is physical, not chemical; its effect is to change the form and not the nature of the raw material worked upon. (4) As to whether the manufacturing is parallel or sequential in its processes, here again it is necessary to analyze the production into its various processes and classify

each. Many of the processes will be found to be parallel. In the making of a desk, for example, certain machines and workmen may be busy fashioning the drawers while others are making the side paneling, and others are making the frame. In the production of each part, and in the final assembly, however, there must be a certain fixed order in the processes. The parts must be cut to size before they can be planed, the frame must be set up before the drawers can be fitted, and the assembly must be complete before the final polishing and finishing can be done. (5) In the usual large furniture factory, manufacturing will be for stock rather than to order. Occasionally orders for special designs of furniture may be received, and there are some factories which cater to the made-to-order business almost entirely. The bulk of the production, ordinarily, would be for stock.

In the same way, you can select any industry and carry it through the various classifications. Such an analysis in the case of your own plant and its processes will give you a clearer grasp on all problems of plant organization, equipment, and operation and make the principles and methods to be discussed in succeeding chapters vital and real in your daily work. If you know the type of

the manufacturing and have its processes accurately classified, you can more readily master the management of men, machinery, and materials which makes the manufacturing successful.

III

The Plant

SINCE the world began, men have used tools to make things. Ten thousand years ago the cave man made his boat or dugout with the aid of tools. His material was a tree trunk, and the tool a piece of sharp stone, but they served his purpose and his work was as truly manufacturing as is the fabrication of a steel vessel in a modern shipyard.

The Plant as a Tool of Production

The development of civilization has gone step in step with the improvement in tools. Great periods of time are spoken of in terms of the prevailing tools. Thus we have the Stone Age, when man's principal tools were of stone; the Bronze Age, with its great advance in the use of tools and implements of bronze; the Iron Age, with its more dependable and resourceful metal. The Industrial Age in which we live today has as its principal tools the numerous combinations of machines which go to make up the factory plant.

Tool improvement has been most rapid in the last century. Power tools, or machines, have largely taken the place of hand tools in many industries. A striking example is shown in the shoe industry. For the manufacture of boots and shoes the United Shoe Machinery Company makes about 400 kinds of shoe machines. Similarly, in the metal-working industries there are numerous specialized machines for cutting, drilling, and stamping.

The modern industrial plant consists of (1) the site, (2) the buildings, (3) the machinery and various auxiliary services. Care must be exercised in the selection, provision, and use of each of these elements, if the equipment as a whole is to be well balanced and is to serve as an efficient tool of production.

Selecting the Site

By "site" is meant the land upon which the factory building stands. In selecting a site, attention must be given first to the choice of region or locality, and second to the choice of a particular spot upon which to build. Let us consider first the selection of the region or locality.

There are four main questions which the factory man asks himself in determining where to locate his plant. These are:

1. Is the location near the sources of supply for raw materials?

2. Is it convenient to the markets which buy the finished product?

3. Is it convenient to a suitable labor supply?

4. What are its transportation facilities?

Influence of Raw Materials

Each of these four factors has an influence which varies according to the type of industry and with changing circumstances. In the case of industries which make use of enormous quantities of bulky material, nearness to raw material is frequently the determining factor. Thus sawmills are placed in the woods where the timber is cut, and iron and steel mills are generally built near coal and iron mines. It was the presence of coal and iron in the neighborhood that made Pittsburgh the center of the steel industry, and it was the discovery of the vast deposits of iron and coal in the Lake Superior region that has caused numerous large steel plants to be built along the shores of the Great Lakes, within easy access by water transportation to those sources of supply.

Many years ago the Lackawanna Steel Company erected a great blast furnace and rolling mills on a hill near Scranton, to take advantage of the coal and iron mines of that vicinity. Later the Lake Superior mines were opened up, and eventually the Lack-

awanna company found that it was bringing great quantities of Lake Superior ore to its Scranton plant, at heavy freight expense. Finally, in order to make use of the cheap water transportation, the plant was removed to Buffalo where the ore could be loaded directly from the lake steamers into the furnace bins. In each case—both in the choice of Scranton and later in the choice of Buffalo—it was the pull of raw materials that determined the location.

So with numerous other industries. Cotton mills are being built in the South because the cotton is raised there. The Columbia river region is the headquarters of the salmon-packing industry because it has the salmon. Flour mills are in the Middle West convenient to the wheat fields. Packing plants are in Chicago, Kansas City and Fort Worth within easy reach of the cattle ranches.

In other lines of industry, raw material seems to have very little influence upon the choice of a site. Take the manufacture of agricultural implements, as an example. Plows, cultivators, reapers, and binders are made of wood and iron, but the principal factories for these articles are found neither in the iron nor the timber regions. Why? Because the manufacturers have found it more important to

Influence of Markets

keep close to the markets in which the bulk of their products are sold than to locate with reference to the supply of raw materials. In the main, it is cheaper to ship raw iron and lumber to a centrally located factory than it is to ship finished plows and reapers from some remote iron district to the agricultural sections. For this reason, this industry keeps close to the big farming region. About the middle of the last century, Auburn, New York, was the principal implement center. As farming spread westward, the industry moved to Springfield, Ohio. At present, with the principal farming operations west of the Mississippi, Chicago and its neighborhood have become the seat of the industry.

Transportation expense is not the only factor which causes a plant to locate near its selling market. If the factory is producing goods which are subject to rapid deterioration, it is important that it be able to deliver its goods to customers as soon after production as possible. This applies to ice plants, candy factories, and other producers of perishable food products. Moreover, there is often an advertising value in having a plant where it may be seen and visited by many people. The Shredded Wheat Company at Niagara Falls has made use of this feature.

Influence of Labor Supply

Perhaps no factor has a more determining influence upon industries than the factor of labor supply. There are hundreds of towns and cities which have become industrial centers simply because the skilled labor of the community has caused additional factories to locate there. This is the case with many of the textile and shoe centers of Massachusetts, and with numerous metal-working towns of Connecticut and Rhode Island. In one New England town a hat factory was established many years ago, and through service in this factory a large part of the population eventually became expert hat makers. Later other hat manufacturers, seeking a location, sought out this town and established their plants there; and the thing that attracted them was the labor supply. Raw materials had to be brought in. The finished products had to be shipped out. But these factors were insignificant in comparison with the all-important question of skilled labor.

Detroit has become the great automobile metropolis of the country largely because of the specialized labor supply which a few pioneer motor manufacturers developed there. Similar causes have made Grand Rapids the chief center of the funiture industry, have made certain cities centers of the

rubber industry, and others centers of the jewelry industry.

Shipping facilities are an important factor. Exceptional advantages in this regard, causing low freight rates, may easily make up for remoteness from markets or from raw material. Two railroad lines are better than one, not only because they provide double the facilities, but because competition between the two frequently affects rates. Water competition is valuable, and has been recognized by the Interstate Commerce Commission as fairly influencing lower rail rates. This is the case because transportation by water being slower, is normally cheaper than rail transportation; and in order to meet this competition the railroads reduce their rates between points which might be reached by water. For this reason a plant is frequently located at a seaport, or on a river or canal. It may make little actual use of the waterway, but because of the waterway it gets lower rail rates.

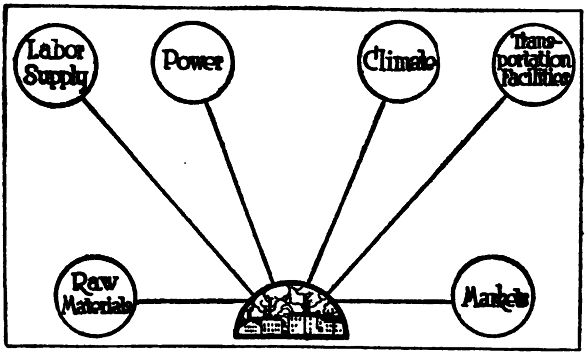
Influence of Transportation

In addition to the four main factors just discussed, there are two minor factors which become of importance in some specialized industries. These are: (1) Power supply, and (2) Climate.

Sometimes the presence of water-power has a determining influence in the choice of

a site. This is particularly the case in industries which require large expenditure of power, such for example as paper mills. In the treatment of wood pulp enormous power must be applied and largely for this reason you will find paper mills situated along rivers where they can utilize cheap water-

Influence of Power and Climate



Factors which influence the choice of location

power. The hydro-electric power generated at Niagara Falls is one factor in the industrial development of Buffalo and its vicinity, though of course in this case there are also other factors—nearness to many raw materials, convenience to markets, and the presence of a large labor supply.

Climatic conditions affect certain industries. A dry climate is necessary to the production of certain chemicals. Some manu-

facturers consider that workmen are more alert and energetic in a brisk northern climate than in the warm semi-tropical regions of the South. To locate cotton mills in the South and get fair results in the manufacture of textiles, humidifiers must be used to maintain correct atmospheric conditions. Not New England's wealth of water power, but its climate, has had perhaps the most influence in keeping cotton mills in New England.

After the regional location of the factory has been determined, the choice must be narrowed down to a particular community within the selected region. Shall the plant be in the city, in the suburbs, or in the country? When the locality has been determined, what rules shall guide in picking the precise piece of ground upon which the plant shall be built?

City, Suburbs, or Country?

Various considerations enter into the answers to these questions. Unit III has already discussed the effect which location has upon labor and employment problems. The advantages and disadvantages of each of the three suggested locations may be summarized as follows:

CITY LOCATION: *Advantages*—Large labor supply; good transportation facilities, both for freight and for employees to and from work; good fire protection. *Disadvantages*—

Has to compete with other industries in getting and holding labor; frequently has to contend with radical and contentious agitators; has high taxes.

COUNTRY LOCATION: *Advantages*—Cheap land and plenty of room for expansion; not subject to strict building requirements, and may build more economically; labor, once it is secured, is more stable. *Disadvantages*—Risk of a labor shortage; lack of community fire protection; limited transportation facilities.

SUBURBAN LOCATION: *Advantages*—Land not so expensive as in city, and not so isolated as in country; city's labor supply is available through interurban trolleys and other lines; fire protection. *Disadvantages*—Nearness to city brings competition with other employers of labor; city growth frequently overtakes suburbs and they lose their suburban advantages.

Selecting the Ground Site

Various details must be considered in choosing the exact spot of ground upon which to build. Good side-track facilities are important, and it is an advantage if these permit of gravity handling of bulky material, such as coal. Allowance must be made for future growth of the plant. Disposal of waste is also important. Factories emitting obnoxious gases are fre-

quently required by law to build in out-of-the-way places. A fertilizer plant on the New Jersey coast was prohibited by injunction of the townspeople from operating except when the wind was blowing out to sea.

Water supply and sewage facilities must not be neglected. If possible the plant location should be high and sightly, with the building's broad sides facing the north and south to catch the light and breezes in warm weather. Employees like to work in a good-looking plant with pleasant surroundings. Convenient transportation for employees is essential. The location must be one agreeable to the class of labor employed in order that the labor supply may be easily maintained without other special inducements.

After all factors affecting location have been considered, the particular site which will yield the largest number of advantages and the fewest number of disadvantages will be chosen. In making his selection, the factory man carefully weighs all pros and cons and picks the site which will be most satisfactory in the long run.

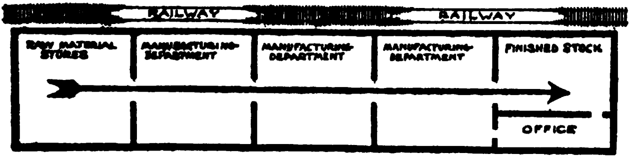
When the site has been fixed on, the next task is to decide what kind of building to erect. Here, as in other questions of planning the factory, it is the character of the

production that largely governs the decision. A steel plant will be housed in a group of one-story structures, while a flour mill or sugar refinery will occupy a tall perpendicular building. A textile mill will be quartered in a long many-windowed building of two or more stories; a factory for explosives in numerous separate buildings of light construction. In each case it is the individual problems of the industry which determine what plan and arrangement the building shall follow.

The Factory Building

Steel manufacturers have found that their processes, involving the handling of heavy materials, like ore, pig iron, and coal, can best be managed close to the ground; therefore their buildings are low and spread out. Sugar refiners, on the other hand, find an advantage in a tall building. Their manufacturing involves the handling of syrupy liquids, which are pumped to the top floor of the refinery, and then pass down through the various levels, receiving a different treatment on each floor, until the finished product emerges on the ground floor. The flour manufacturer utilizes the force of gravity in much the same way. Because of the risk of explosion, the manufacturer of gunpowder divides his plant into numerous small units and places each in a separate building. An

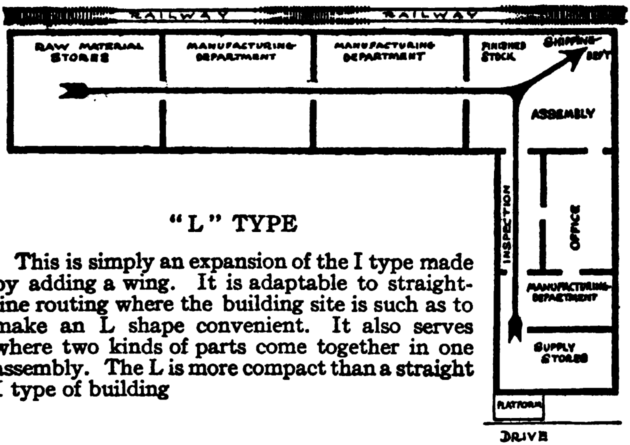
accident in one unit may then be confined to its own building, and fire or explosion in one need not mean disaster to the whole plant.



"I" TYPE OF FACTORY BUILDING

Showing flow of production from stores through various manufacturing departments to finished stock

Perhaps the type of building mentioned as typical of textile plants is the one used by a majority of manufacturers. Such a build-

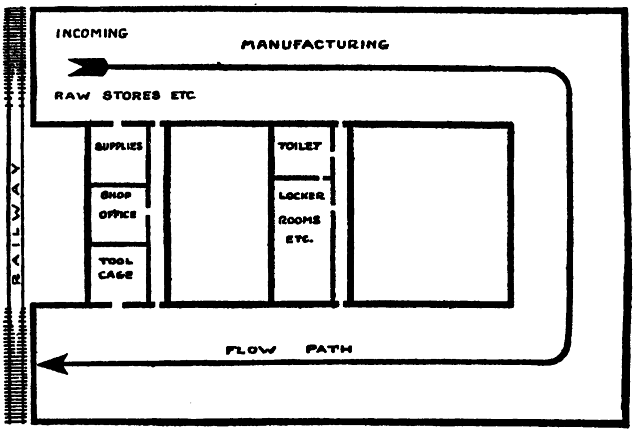


"L" TYPE

This is simply an expansion of the I type made by adding a wing. It is adaptable to straight-line routing where the building site is such as to make an L shape convenient. It also serves where two kinds of parts come together in one assembly. The L is more compact than a straight I type of building

ing, with large floor space and large window space, is the type best adapted for the hous-

ing of numerous machines and operatives. Where ample ground is available, one large one-story building may be used to cover a wide area. In this kind of building it is customary to use a sawtooth roof with skylights for lighting the interior. Such a building is less desirable in warm climates than



"U" TYPE

Gives a longer flow path and more room than L type; it also allows space for service rooms between the wing

one of several stories, since the wide expanse of roof makes it difficult to keep cool in summer. A building with several stories is the usual plan followed by a factory in the city or suburbs, where the cost of land prohibits spreading out. Such an arrangement permits of the use of gravity conveyors, and simplifies the problems of heating and lighting.

Although the building may be planned to fit the processes, nevertheless, like tailor-made clothing, a few principal styles predominate. The simplest style is a single building whose ground plan roughly represents the letter I. The enlargement of such a building may take the form of two or more parallel buildings, each duplicating the original. Or it may be made in the L style by adding a wing to the original structure; or it may be made in the U style by adding two wings. Other styles, which take their names from the letters of the alphabet which their ground-plans suggest, are the E, F, H, and T types.

Types of Construction

Not only the plan of building, but also the type of construction must be settled upon in advance. There are four classes of factory construction: (1) Ordinary frame, in which the buildings are entirely of wood; (2) Slow-burning, in which the walls are of brick and heavy wood framing; (3) Steel-frame, in which there may be curtain walls of brick with wooden floors and the steel framing exposed, or the steel may be fireproofed throughout with concrete or other material; (4) Reinforced concrete.

Safety requirements, insurance rates, absence from vibration, and ease of keeping clean, are points which affect the choice of construction. In general, except in indus-

tries whose nature requires very cheap buildings, fire-proof construction, of steel frame or reinforced concrete, is largely employed. The New England type of slow-burning mill construction is still popular, however; when protected by a sprinkler system against fire, it is a good insurance risk.

In the latest type of factory building much of the wall space is given over to windows, thus providing the maximum of daylight and air. Provision must usually be made for tool rooms, toilet and wash rooms, coat rooms, shop offices, and various services. These may occupy 25 per cent, or even more, of the total floor space, and are frequently provided for in an ell or wing of the building.

Equipment

The final element in the makeup of the industrial plant is the equipment. This includes tools, machines, power installation, and all other fixtures and furnishings necessary to the carrying on of operations. The prime factor in equipment in the average plant is machinery.

Machinery is of three kinds: (1) the hand-controlled, (2) the semi-automatic, and (3) the full automatic. The hand-controlled machine is one which must be continuously fed and directed. Examples are the engine lathe and the ordinary domestic sewing machine. The semi-automatic machine is one

Exterior of Modern Factory with Maximum Window Space —Plant of Wilder Tanning Co., Waukegan, Ill.

Interior of Modern Well-lighted Factory—Plant of Baker-Vawter Company, Benton Harbor, Mich.

which performs some of its operations without action by the operator. Such is the case with some turret lathes which will automatically complete a metal cutting operation after the operator has turned the turret and fed it up to the stock. The full automatic machine is one which is self-feeding and performs its work without other attention than that needed to keep the machine in proper adjustment. Automatic screw machines, spinning machines, and power looms are examples. A single operator can usually care for two or more of such machines.

The methods of production have changed as man has advanced, but the principle of using tools to transform material is the same today as it was with the first tool worker. In the factory with full automatic machinery, the machine itself largely embodies the element of skill formerly supplied by the workman. Factories where this type of machine predominates are of fairly recent development, and are usually of large size.

How Big Shall the Plant Be?

Various factors must be considered in determining how large to make the plant. It is not only a question of how much output you wish to produce, but also one of the character of the production and the type of operations used. For example, to establish a textile mill of

two spindles or two looms would be poor business. Cost of attendance, rent, power, supervision and other overhead expenses would be too great in proportion to the output, and a mill of such small size would be unable to compete with mills operating numerous machines. On the other hand, a man desiring to establish a printing shop could equip it with one small job press or with a dozen large power presses, and might be equally successful in either case, depending upon the amount of business he could get. The type of operations used makes the difference. In the spinning mill where machine production is the rule, large units are practically essential to profitable production. In the printing industry, where hand work plays so large a part in the production, the plant unit may be as small as market conditions or the desire of the owner may dictate.

In other industries, the very character of the production determines whether the plant shall be large or small. A sugar refinery, for example, requires a large investment in plant. The nature of the manufacturing is such that a man must build a unit of large capacity, or there is no profit in the business. A cotton ginnery, on the other hand, is usually a small plant consisting of a relatively few ginning machines and one or two presses. This is the

case because the nature of the industry requires that it be convenient to the cotton plantations, so that the farmers may haul their cotton to the ginnery with the least expense and inconvenience. As a result, you will find small cotton ginneries scattered all through the cotton belt of the South, thousands of them, instead of a few large ginneries in the cities.

In some industries, an individual piece of equipment determines the size of the plant and all other equipment is auxiliary to it. This is the case with a paper factory, where the size of the paper-making machine governs the size of the plant, and with a steel mill, where the size of the blast furnace is the determining factor. Larger plants of this kind are simply multiples of such units.

In determining each question with reference to the plant, therefore, the factory man must be guided by the individual needs of the particular industry with which he is dealing. In selecting a site, in deciding upon the plan of building and type of construction, and in choosing and laying out the machinery, he must look at the problem from the point of view of his own industry, his own factory, his own expected output. The foreman who can get this same point of view with reference to the plant in which he is a squad

leader, will understand its organization and its processes more thoroughly and will find himself growing in efficiency of teamwork and in leadership.

IV

Laying Out the Plant

THE arrangement of a factory plant is usually shown by drawings. These may consist of several different sets of blue-prints, some showing general and detail construction of the buildings, others the location of the various equipment or the routes or paths by which material passes through the works.

The building plans are generally made by an outside engineer or architect to suit the wishes of the owners. It is a great advantage if the buildings can be built to meet the special needs of the industry which it is to house, for then everything can be laid out in advance for most efficient operation. Often existing buildings must be used and the equipment layout arranged as well as conditions permit.

Planning in Advance an Advantage

In setting up a new plant or rearranging an old one, it is necessary first to decide upon the route the material should follow and then make plans to show the placing of all equipment. In any well-planned industry, the plans should fit the process. The plant exists

for one purpose—to make its product with the least waste of material, labor, and plant capacity. This result is possible only when the arrangement of equipment conforms to the particular requirements of the manufacturing.

To make the plans fit the process the same method is followed whether the plans are for building a new plant or for adapting an old one. One must first obtain a thorough knowledge of the process, of the kind of labor needed, and of the results to be attained at each step or operation.

Data that Guide the Layout

All of this information should be carefully recorded. A list should be made of all operations, omitting none, however small. A list should also be made of the kind and amount of material to be used and of all the machinery or special equipment required. Drawings or specifications, or both, should be drawn showing completely what is to be made. For example, in a metal-working industry for interchangeable manufacture, the following complete sets of plans should be made:

1. Drawings of the product and its parts.
2. Drawings of gauges for use in manufacturing parts.
3. Drawing of tools needed in manufacturing parts.
4. Drawings of fixtures needed in manufacturing parts.

5. Specifications, covering material to be used either in the product or tools, etc., its heat treatment, etc.
6. Complete list of operations.
7. Plan of equipment needed for manufacturing.
8. Plan of material needed for manufacturing.

Not all of this data bears directly upon the layout of the plant, but such detailed information must be prepared before manufacture can be started. Such information shows very clearly the factors to be taken care of in the plant.

The plan of equipment shows what is needed in the layout. The operation list shows the order or sequence in which the equipment will be used. The plan of material should show the rate of production contemplated and from that estimates may be made of the amount of work in process to be provided for. The specifications show the quality of work to be done. Altogether the drawings and plans mentioned give the information necessary to start to lay out the plant.

The Process Chart

A convenient way to record the information needed is by means of a Process Chart. Such a chart shows graphically and clearly every material and every operation; it pictures specifically where, when, and what work flows through the plant

and the order of its movement. To make such a chart, it is well to start with each material that directly enters the product. The amount of material per unit of production should be determined and recorded upon the chart. At the same point should be noted the name of the operation to be performed on this material. Operations should be shown on the chart in the order in which they occur. Connecting lines or arrows may be used to indicate the flow from operation to operation. The quantity of material passing each work-point must be sufficient to allow for loss or waste in process.

Often a part of the product is treated in one way and the rest in other ways. This should be shown on the chart. Where a variety of products are made, separate charts should be prepared for each unless at one or more points all pass through the same operation.

Flow of Work

Under the ideal condition of plant operation there would be a continuous flow of material from outside sources through the plant and out again into the market. In passing through the plant the material is transformed by the factory processes in such a way as to increase its value. The more quickly this transformation takes place—the shorter the period the material is

Sequence	1					2				
Operation	Material		Equipment	Labor	What do	Material		Equipment	Labor	What do
	Kind	Amount								
A. Make Body Paper	D. waste paper Mch. Broke Box Broke Silicate Alum	1500 lbs. 1000 lbs. 1000 lbs. 5 gals. 10 lbs.	Allen Engine No. 4	1 Operator 2 Helpers	Beat pulp 30 min. Dump and wash down with water			Paper Machine No. 2	1 Mch. tender 1 Back tender 1 Helper 1 Winder	Make sheet 108″ wide by .005″ Rolls 800 lbs. each
B. Make Lining	Sulphate Sulphite Color No. 3 Size Alum	1500 lbs. 1000 10 15 5	Allen Engine No. 1	1 Operator 2 Helpers	Beat 1 hr.	Thru Jordan No. 8				

A SIMPLE TYPE OF PROCESS CHART

A and B are parallel operations; 1 and 2 are sequential

in the works—the less will be the cost of the added value and the greater the profit. This is true because overhead expenses, such as rent, taxes, interest on investment, salaries and the like, are going on all the time, whether production is rapid or slow. By increasing the rate of production, the per-unit expense is proportionately decreased. (However, because of market conditions and other factors affecting certain lines of manufacturing, it will not pay to increase plant cost for the sake of rapid production beyond a certain point. This point can be determined only by estimate based upon actual conditions.)

The flow of work through the plant should be uniform except as it becomes necessary to vary it to meet market conditions. If proportionately more material enters than leaves, the material stores will be increased to a dangerous point. If proportionately more leaves than enters, the stores will be reduced; and if this condition continues, the plant will ultimately have to shut down. It is necessary to vary the amount of material on hand to suit the conditions affecting delivery of raw materials to the works. If the raw material supply is limited or transportation to the plant is slow or doubtful, the plant must keep on hand a much larger supply than

is necessary when raw material is abundant and transportation quick and certain.

In any case, the amount of material in process should be kept as small as possible without interruption to operations. The crude raw material is likely to be a much better asset in the event that it becomes necessary to turn it into cash quickly, than material which is partially processed. The continuous-flow plan, or straightline routing, is generally to be preferred for most factories. It has the advantage not only of a minimum amount of handling, thus saving labor, but also of materially decreasing the quantity of work in process. The latter advantage enables the management to obtain a rapid turnover of stock.

Pin-Plans and Layouts

As soon as the operation lists are made and information is available regarding the kind of equipment, the floor space required by the equipment, and the amount of power required to drive it, a preliminary pin-plan may be made. To make a pin-plan, first lay out a plan of the entire floor space of the room or building. Then make drawings of the floor space to be occupied by each piece of equipment. These drawings should be drawn to scale, cut out, and each marked with the name of the machine or other equipment which it repre-

sents. They may then be pinned upon the floor plan in the order desired, or shifted about to show how different arrangements would appear. Various colors of cardboard may be used to distinguish between the classes of machinery or equipment. Colored strings may be wound about the pins, going from one piece of equipment to another to indicate the travel of material through the works.

By studying these plans and trying out different rearrangements of the cut-outs, a final satisfactory layout is arrived at. A drawing copy should then be made. It is of vital importance to check all dimensions of equipment and buildings to insure that the arrangement adopted is practical and can be installed. The drawing showing the arrangement of the equipment can be used as a basis for the drawings of power lay-out—showing the method of driving the various machines, the location of motors, the line shafting, etc. In a similar way, the layout for the electric circuits for lighting, and the layouts for the supply of water and heat, can be made.

Storing Work in Process

In making these layouts for the pin-plan, proper consideration must be given to the storage of incoming material, of work between operations, and of finished work awaiting removal. While space should not be wasted, there

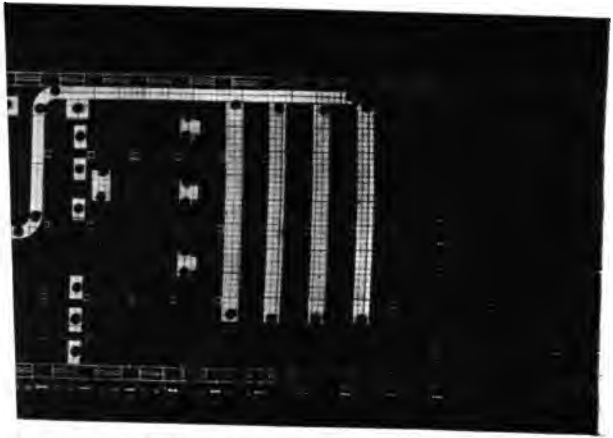
must be provision for all necessary articles involved in the production.

Many products are handled in special racks or tote boxes which are stacked beside the machines. Floor space must be allowed for these stacks in proportion to the volume of material to be cared for and also to permit easy handling, especially if trucks are used. Where automatic conveyors are used, some arrangement is necessary to keep sufficient material near the machine. In many cases, gravity conveyors keep a stock of work on the conveyor near the work-point.

It is very undesirable to crowd the work-room by having too much material or stock near the machines. If the production methods are such that considerable stock is necessary between operations, it is well to provide for storing this in a separate room or basement, but not further than necessary from the point where it is next to be processed.

Aisles and spaces for the workmen should be kept clear. So important is this considered in many plants that guide lines are painted upon the floor to show the aisles and also the places to locate incoming and outgoing work.

Provision should be made for keeping a record of the amount of material at each point and for guarding it against spoilage or



NARY LAYOUT OF MACHINERY

resent equipment. They are fastened down with the
ed about until a satisfactory arrangement is secured.
 the upper center, around which the line of machinery
ool room

misplacement. This is done by having racks with a fixed number of spaces or by having tote boxes whose weight or count has been recorded by tally men. The tally men, or some other definitely authorized persons, should be responsible for the movement of work and for its protection while not actually in process.

Auxiliaries and Service Rooms

But in laying out the floor space, the productive equipment and work in process is not all that must be provided for. Certain auxiliary machinery is usually necessary for keeping the regular equipment in good repair and for making quick adjustments. This machinery must also be provided for.

Various plans are common. Some of the auxiliary equipment may be distributed among other machines in the same room; or it may be separated from the other machines by partitions, though stationed in the same room. Another plan is to place all such equipment in a separate room or building. The main point is to avoid unnecessary transportation and save time for the workmen—whichever arrangement does this is the best.

Certain service rooms are indispensable. These may consist of small stock-rooms, tool rooms, coat rooms for the operators, wash rooms, toilet rooms; and first-aid rooms.

Branch stock-rooms may be used to store work in process or to carry supplies that may be necessary in connection with the operations in a given room. The tool room contains the supply of tools necessary for the shop which it serves.

Coat rooms for the operators are generally placed so as to be accessible to the workroom (though not open in working hours) and also near to wash rooms and toilet rooms. It is desirable that lockers be provided, so that each employee has a place in which to lock up his clothing and his lunch. Sanitary steel lockers are somewhat expensive, but nothing else is quite as satisfactory.

The Influence of Power

The source of power may have an important bearing upon plant layout, though electric transmission of power with electric-motor drive has now become so common that factory buildings are no longer limited to positions next to a power plant. In some cases, however, the power application is so simple that there is advantage in placing the factory or mill building where the machinery may be directly driven by geared connection to water-wheels; or by rope or belt drives from steam, gas, or oil engines.

Most factory plants must have heating plants and artificial light. After it has done work in a steam engine or turbine, steam can

be used for heating purposes with nearly as good effect as when sent directly into the heating system from the boiler. As a result, when comparatively large amounts of steam are needed for heating, it is possible to produce steam power very cheaply. When relatively small amounts of steam are needed for heating purposes, it may happen that power may be purchased from a large central electric-power station at a lower rate than it can be made by the much smaller factory power house.

In deciding upon the power supply one must consider these questions: (1) Is the power cost a large percentage of the production cost of the product? (2) Is there a large demand for steam for heating or factory processes? (3) May constant speeds be used or must there be provision for wide speed variation? (4) Is water power available? Must much water be used in factory processes?

The customs of the industry under consideration will usually indicate answers to these questions, but if the annual power cost is large, the power supply should be selected with the assistance of an expert in power supply.

For the best supervision and maintenance of proper shop discipline it should be possible to view the entire shop from some one point. It is common in many industries to have a small shop-office for the foreman and super-

visory force in each workroom. The supervisory force includes timekeepers, tally clerks and various assistants. Provision would also be made here for keeping record of the operator's time. As has been suggested, there is an advantage in throwing all of these various service rooms and facilities into a wing of the building. If mechanical conveyors are installed, various service rooms may be very much in the way unless they are provided for in wings or ells.

The Use of Conveyors

Rapid flow of work through the plant is greatly assisted by the use of automatic conveyors. They help to improve the manufacturing efficiency. There are various sorts of conveyors available, depending on the nature of the product. The work may be handled (1) on ordinary trucks or on elevating trucks; (2) it may travel automatically on gravity conveyors, or (3) on belt conveyors, or (4) it may be forced through pipes or blown through air ducts. It is necessary to determine in advance which system may be best adapted for the work.

Proper conveying plays such an important part in factory efficiency that the subject should be carefully studied. The simplest system is that which uses the ordinary hand truck; this system involves lifting the work on to the truck and then after it has

been carried to the proper point lifting it off. Another plan for trucking is to use a specially constructed rack or platform on which the work may be piled in predetermined order, these special racks or platforms being handled by the use of elevating trucks. In this way, a few elevating trucks may do all the trucking in a shop of considerable size. Trucking may also be carried on by the use of motor-driven industrial trucks. These are small trucks using storage batteries for power. For trucking considerable distances in factory yards and between buildings they are very satisfactory. They are also made of the elevating-platform type.

Gravity Conveyors

One of the most satisfactory means of conveying is the gravity conveyor. It uses practically no power. Moreover, it may be arranged to have a large storage capacity, feeding material down as it is needed, and in this way caring for a considerable amount of work in process. An indirect advantage of gravity conveyors is the fact that they automatically stop and start. In installing gravity conveyors, the pitch must be carefully determined and a type selected having the best possible bearings for ease in rolling and low cost of maintenance.

Travelling belts are useful in places where

the work must travel along the same level. In the assembly of time fuses, for example, a bench was arranged with a horizontal travelling belt running before one hundred girl operators. As the work passed along to each operator, it was necessary that she remove it and perform the operation assigned to her. The work must then be returned to the belt, and pass along to the next operator, and so on. In using conveyors in this way, it is necessary to arrange the machine-speed to match that of the operator. It is also necessary to have enough extra operators to keep the places at the table always filled. A striking illustration of the marked efficiency which is given to manufacturing operations by travelling belt conveyors is the use of such conveyors in the Ford Motor Company plant, in assembling automobiles. The same principle has now been adopted in many automobile factories. The use of such a belt has made it possible to obtain a speed of assembling which had not formerly been thought possible.

The same principle has been made use of in the Ford plant which was erected for the construction of Eagle boats or submarine chasers. Here a boat some 250 feet long is built upon what is in effect a flat-car. At one point certain operations are started, then

the car moves to the next point and other operations are done, and so on, the work progressing continuously until finally it rolls on to an elevator which lowers the entire car and completed boat into the water.

Conveyors save labor of handling, decrease the amount of work in process, and most important of all, increase the rapidity of flow of work through the plant. In this way manufacturing efficiency is increased.

Arranged by Sequence or by Type?

There are two main schemes of factory arrangement. One lays out the plant in such a manner that the equipment is arranged in accordance with the sequence of operations, and regardless of their character. In the other scheme, the layout provides for grouping the classes of work according to character. For example, in a machine shop manufacturing great quantities of the same article, a group of lathes might be followed by a group of drill presses and these in turn by a group of milling machines, and then another group of lathes as the sequence of operations required, all being located in one room perhaps. On the other hand, all lathe work might be grouped in one room, all planer work in another, and in still another all milling machine work might be put. In a clothing factory, all cutting operations

might be in one room, all sewing machine operations in another, all hand sewing in another, and so on.

Consider the two schemes of factory layout as applied to an electrical industry that manufactures electric motors, transformers, and such machinery. Here iron castings must be machined, sheet metal must be blanked out, and electric-wiring must be done. In the one scheme of layout, the castings would all be machined in one shop, regardless of whether they were for use in transformers or motors. The sheet metal blanking would be performed in another shop, and the electric wiring in still another. By the other scheme, in which operations are performed in sequence, a transformer would be made complete in one shop and the motors in another. Thus, in the case of either motor or transformer the iron castings would be machined, the sheet metal would be blanked, the wiring would be done, the parts assembled, all within the one shop or group of shops, the operations taking place in the order necessary to the construction.

In some of the larger industries it has been found more efficient to lay out the work to provide for the operations in their regular sequence rather than group the work by character of operation. In small factories, or

where otherwise some of the machines would not be operated to capacity, it is usually better to group the machines by type.

Planning for Future Growth

The possibility of future growth must be kept in mind in laying out the plant. Equipment should be provided and placed with this idea in view. Excessive space should not be left empty, of course, but consideration should be given as to how additional space may be readily obtained when it becomes necessary. If the factory layout provides for a straight-line flow from operation to operation, it is often possible to add a parallel series of operations in a new building unit. If the layout is by character of work, enlargements may be made only by providing more space and equipment for each workroom. It is customary in laying out new factory plants to take for granted a certain expected growth and indicate upon the plan the space to be added when that growth is realized. By this method there may come a time when the factory growth has been such as to develop a well-balanced plant as a whole. Then it may be better to provide for further growth by the construction of a branch factory elsewhere.

Increased business does not always call for plant expansion. Under special stress, extra output may be obtained by the operation of

a night shift, if that plan of operation is not already in use. Of course, these questions will be determined by the man who is at the head of the factory. He may be president, works manager, or superintendent, but whoever he is he must have a thorough knowledge of all the factors of the business. And such policies will be most successful if foremen understand the principles upon which they have been determined, and are thus able to cooperate with full knowledge of the "why" of the particular system to be followed.

V

Selection of Equipment

THE careful factory organizer and equipper will keep in mind six fundamental rules in selecting plant machinery:

1. Have machinery too large rather than too small.

2. Have machinery too strong rather than too weak.

3. Make sure that all moving parts are easily accessible for inspection, adjustment, or repair.

4. Have machinery as simple as possible.

5. Have the machine embody the element of skill as far as possible.

6. Make sure above all, that the machinery will do what is required of it.

Factors in Choosing Machines

The experienced factory man, in choosing machinery, asks himself these questions: Does the machine show the lowest operation cost or can the process be handled more economically by hand, or by some other machine? Will the machine often be idle?

Can it be adapted to other uses or sold at a fair price should it no longer be needed in its present position? Could a simpler machine do the work as well or as cheaply? Is adjustment easy? Is good lubrication provided? Are there proper safeguards?

Experience gained from war contracts in 1914 and 1915 taught many an American manufacturer the importance of careful selection of equipment. In numerous cases, the machinery was not good enough to give the very accurate results required. In other instances, expensive automatic machines were purchased and installed only to be discarded later and replaced with simpler machinery when it was shown that the less complicated equipment would do better. Indeed, the first two years of the war were a period of intensive training of manufacturers in the requirements of mass production, in which they learned much of the importance of careful choice of equipment.

In selecting equipment, the first matter to be considered is the design or make of the machinery. If the factory is already operating, and it is a question of providing additional equipment, there is much merit in uniformity even if the style is not the latest. The cost of maintenance will be decreased and

Keeping Equipment Uniform

operating problems simplified by having all of the equipment of uniform type, provided of course that satisfactory results can be obtained with this style.

It often happens that one's choice is limited by the amount of money that may be spent on equipment. Often the buyer must select less expensive machinery than that which will give the highest machine efficiency. Machine efficiency, however, is not the most important point. There is production efficiency, or capital efficiency, to be taken into consideration. In the final result, that equipment gives the highest efficiency which enables the manufacturer to make the best return upon the capital invested. The probable permanence of the business or the uniformity of that business during the year may determine the amount of money which may be invested.

How Labor Supply Affects Choice of Equipment

Then, there are various other factors which affect the selection. If the labor supply is such that skilled employees may be readily obtained, it may be expected that whatever equipment is selected will be well cared for, but if unskilled labor must be used, and skilled labor is scarce, it is highly desirable to have machinery of a type which calls for the least attention on the part of skilled employees. If the labor supply is

abundant, it may be used freely and less may be required of the machines. If labor is likely to be scarce or high-priced, machinery should be selected that is as automatic as possible, so as to require the least number of employees. Of course, if the volume of production is relatively small the problem of selection is altered considerably, as then it may be best to do by hand what otherwise might be done by machinery.

Simplicity of mechanism is of great importance. In many cases, much simpler equipment can be used than at first seemed possible. Many a complex and very expensive piece of equipment has failed because it was too intricate to keep in good running order without excessive oversight and expense.

The experience of other factories is generally of great value as a guide. Specialized makers of machinery usually have on file extensive reports of the experience of manufacturers who have used their equipment, and such records are open to new or prospective purchasers of machinery. By consulting them, one may usually find the equipment that is best adapted to his manufacturing problems.

Some types of equipment call for the payment of royalties on the product. This is the case, for example, in most of the ma-

chinery used in making shoes. Sometimes the machinery manufacturer does not sell the machinery, but merely leases it, and requires a royalty (or per unit payment) on all production turned out at the machine. Patent rights must also be taken into consideration. Rival machines are patented. If the machine is a new type recently invented, one must be especially sure, in purchasing it, that he will be fully protected against suits for infringement.

When an analysis of the work to be performed indicates that the equipment is not as efficient as it might be, the manufacturer may feel warranted in designing and perfecting his own special apparatus or machinery. This is usually a very expensive proceeding, however. It is justified only where manufacturing on a large scale is to be undertaken and the increased earnings will more than make up for the extra expense of special made-to-order machinery, or where there is good prospect of realizing a good return through sale of patent rights on the new machine or through royalties.

Mention has been made of automatic machinery. If the volume of production is small, automatic machines are frequently not an economy. A screw machine, for example, is a convenient rapid-working apparatus for

producing small parts. But suppose the particular needs of the factory require only a limited number of the parts. Then the machine would stand idle a good part of the time, and the advantage of its speed and capacity would be lost. It would be more profitable under these circumstances to make the parts on a simple lathe, which may be used for a variety of machine operations, rather than to tie up a large part of the capital in the specialized automatic screw machine.

Automatic Machinery

But where large-scale continuous output is required, an automatic machine is a big gain and should show a direct saving in labor cost. Under such circumstances, the annual saving due to the automatic feature is usually sufficient to repay in a short time the increased outlay involved in providing the equipment. In estimating this saving, not only the initial cost but the cost of repairs and maintenance of the complicated machine must be taken into account. In some cases highly automatic machinery is so delicate and expensive to maintain that it is profitable only under the most favorable circumstances.

The power requirements and limitations must also be borne in mind in selecting equipment. Is it to be driven by shafting and belting, or by direct connection with electric

motors? The direct electric drive, with a separate motor for each machine, is coming more and more into practise in modern industry.

Getting Equipment that is Adaptable

In selecting equipment, as well as in planning the building, care is given to possible future developments in the plant and an effort is made to take care of these as much as possible. The future use of machinery may be different from the present. Changing conditions affecting the demand for output may call for much heavier use of the machinery than is at present necessary. It may be necessary to make a different though similar product, or an entirely dissimilar product may be required. The manufacturing processes may be altered for one reason or another. Changes from belt drive to electric-motor drive may be introduced. Routing conditions may change. All of these possibilities may affect the usefulness in the future of the equipment selected now, and the wise factory man keeps them in mind in his selecting.

Most machinery is adjustable and may be equipped with various attachments. By making use of such adjustable features and of such attachments, it may be possible to vary the kind of production or modify the

output as desired. Likewise, most equipment may be altered in speed and in rate of feeding the work. The difference in first cost between machinery which is adjustable and that which is not, and between machinery which may readily have attachments added and that which may not, is not great; and it may at some time save the purchase of a new machine, or save the machine itself from the scrap heap.

Factors which Govern Efficiency

What is aimed at in every case is *efficient equipment.* Efficient equipment produces the right quality of product in the right quantities with the least cost for power consumption, repairs, and maintenance. A machine is not efficient if it requires excessive labor to operate it; it is not efficient if it is constantly calling for repairs. The final proof of its efficiency lies in the ultimate low cost of the operation.

Not many years ago a concern in the middle West bought a steam engine which had been built in Belgium and had an extremely high steam efficiency. After a year or more of trial the Belgian engine was discarded in favor of a simpler American Corliss engine. The Corliss had a lower efficiency so far as steam consumption was concerned, but it was much easier to maintain and really cost the owners less in repairs than the other sup-

posedly more efficient piece of equipment. It is the ultimate low cost that counts. Economy in one item at the expense of high maintenance cost should be avoided.

In many instances, the speed of the machinery determines the quantity of output per day or per hour. This speed may be entirely dependent upon the machine itself or the product which it handles, or it may depend upon the speed with which the machine's operator can move.

For example, the limiting speed of power-operated sewing machines is the point where the thread will break; the limiting speed of certain looms is the point at which the yarn will break; the limiting speed of hand-fed power presses is the speed with which the operator can feed the press. In some cases, the quantity of output per machine may be greatly increased by changing from hand feed to automatic feed. Where the product itself limits the speed, the conditions can often be altered and the equipment modified in such a way as to permit of increase.

Quality or grade of output is usually the first consideration in manufacturing, although not the one which determines the greatest earning power of the equipment. The manufacturer who has established a reputation for automobiles, shoes, soap, or watches of a cer-

tain quality must keep the grade of his product up to standard or he will lose his trade and more careful manufacturers will win it. Thus, the grade or quality of work which the equipment is capable of performing is an important item. Manufacturers working upon government specifications have learned the need of making goods of exactly the proper quality. When the equipment has been such that it would not produce work within the limits of the specification, quantities of the product have been rejected at a great expense to the manufacturer.

Quality of Output as a Factor

Sometimes the power consumption of the equipment is an item of great importance in selecting machinery. Steam or other power used in operating a paper mill might be so large a percentage of the total cost of operation that a machine which saved power would be a factor in lowering the cost of production. In another type of manufacturing, the power requirements of the equipment may be so small that a slight difference between two machines in this regard would be of no importance. In some cases, by speeding up the machinery at the expense of added power, the output may be so largely increased as to more than offset the added cost.

In a general sense all equipment used in

manufacture is included under the term "tools," the plant itself being called a tool of production. Moreover, some machines, such as lathes, planers, power drills and the like, are referred to as "machine tools." But the common usage of the term "tools" in modern production makes it include only hand implements or small tools which are set in a machine.

Selection of Tools

Where formerly it was the custom for most tradesmen to have their own tools and use them in the shop, it is now almost universal practise for the factory to supply all tools required by the workmen. In many cases these hand tools wear out more rapidly than other pieces of equipment. For that reason it is a practise in some industries to charge off one-half the value of such tools when they are first purchased, thus anticipating their depreciation. As with other classes of equipment, tools should be selected with a view to ultimate economy in operation. If the tool is one to be used in a machine, the loss in time due to changing it is considerable; accordingly it is frequently economy to buy a tool which, while more expensive, has a longer life, and requires less frequent stoppage of the machine. Likewise with hand tools which must be frequently re-sharpened or re-dressed; the cost of this treatment is an item

that may be reduced by selecting good tools in the beginning.

Tools that are not in continuous use are kept in the tool room where they may be loaned out as needed. The tool room keeps in stock such items as portable electric drills and grinders, monkey wrenches, screw drivers, measuring instruments, and special tools necessary for use in connection with the machinery. Efficient organization requires that there be a system of caring for such equipment so as to insure the least possible loss from damage or failure to return the tools to the tool room. In some cases, pieces of machines or spare machine parts are considered as tools and carried as such in the tool room. Policy in this respect will vary at different times and in different factories.

Gauges as Part of the Equipment

Closely related to small tools are gauges. Gauges are extensively used in the manufacture of interchangeable parts. In order that work may be produced in large quantities without the need of delay for fitting or assembling the work, all parts must be made exactly alike; that is to say, it must be possible to interchange one piece with another in any assembly. In order to insure that all parts are the same it is customary to use gauges

which will measure the sizes of the work between fixed limits.

In this kind of manufacturing, the work proceeds according to a complete set of working drawings showing all dimensions, style of finish, and any special treatment. The dimensions are given within limits, as $1.470'' \pm .005''$; which means "one and four hundred seventy thousandths inches plus or minus five one thousandths of an inch."

The gauges must be designed to measure the work within these limits. Usually there is a "go gauge" and a "not go gauge." The "go gauge" is made to the lower limit of size and all the work should go into it. The "not go gauge" is made to the other limit, and none of the work should enter it; if a part fitted in the "not go gauge" that would show at once that the piece was too small. By the use of such gauges an unskilled operator may gauge work very closely.

In a large factory it is usually necessary to have various sets of gauges. It may be necessary to have three gauges for measuring the same dimension. One may be kept in the work room, the other may be used by the shop inspector, and a third may be used by the final inspector or by the inspector for whom the product is being made. In order to safeguard against error the manufacturing gauge

should have a little closer limit than the gauge in the hands of the shop inspector; and the shop inspector's gauge should be of such dimension that anything passing his gauge will pass without question the gauge in the hands of the final inspector.

Gauges wear, and it is necessary that they be inspected at frequent intervals to see that no variations have developed. When the wear has reached a certain point, repairs must be made. Care must be taken in distributing repaired gauges back to the shop and to the inspector.

Tolerance Dimensions

The establishment of tolerances, or allowable variations, on the work to be manufactured has made it possible to use gauges. It is likewise desirable to establish tolerances for the gauges themselves. The fact that it is not possible to work to an exact dimension is recognized and so it is customary to specify that the gauge shall be so much, plus or minus, perhaps, one ten-thousandth of an inch.

Gauges are most generally used in connection with interchangeable manufacture of metal parts, but the gauge principle can be applied to almost any industry. That is, in practically every kind of production it is possible to use some simple mechanical device for determining readily whether the product measures up to specifications.

Another class of equipment that is largely used in modern production consists of jigs and fixtures. A jig is a device employed usually in connection with machine tools to insure rapid duplication of work. For example, suppose the production calls for the drilling of three holes in each of a thousand steel plates. The plates are of exactly the same size, and the holes are to be drilled in correspondingly the same three points in each. To measure each plate and mark the three points for drilling, and then to put the plates through the drill, carefully guiding each so as to drill each hole exactly right, would require a large amount of time from a skilled machinist. By using a jig, all of this measuring and careful guiding is rendered unnecessary. The jig holds the material in place, indicates where the holes are to be drilled, and guides the piece of work through the drilling operations. At the same time, a workman of much less skill is able to do the work.

The Use of Jigs

Jigs are used principally in connection with drilling and boring operations. Three results are achieved through the use of jigs: (1) exact duplication of work, (2) rapid work, (3) less demand upon the skill of the workman. By using jigs two parts that must mate together can readily be made separately

and accurately; in making jigs for such parts, however, it is generally advisable that they be made in pairs to insure correct alignment. Only where a number of operations are to be repeated it is profitable to use a jig. For example, it would scarcely be worth while to make a jig to bore the holes in one plate or in three plates. Careful planning and precise workmanship must go into the making of a jig; and where only a few parts are to be made this careful planning and precise workmanship can just as well be spent upon the actual work of producing the parts.

In making a jig, the locating and clamping devices should be such as to enable one quickly to place the work in it, and it should be impossible to put the work in the jig in the wrong way. In other words, it should be as nearly fool-proof as possible. Jigs must be made heavy enough to hold without springing when the work is clamped in them and the clamps must be so arranged as to avoid springing the work.

The Use of Fixtures

A fixture is a holding device used in connection with milling, planing, slotting, and shaping machines. It does not serve to guide the tools; its purpose is rather to hold the material securely and correctly with reference to the machining operations. Fixtures are in many cases very ex-

TWO VIEWS OF A DRILLING JIG

This jig is used in drilling a rifle part. In the upper picture, the jig is open and the part is shown in place. Below the jig has been closed and locked and is ready for drilling

pensive. Like the jigs, they are used only when the operation is repeated many times.

In mass production the use of jigs and fixtures enables rapid handling of work by labor that is relatively unskilled, and great economy is effected. The number of these to be supplied has definite relations to the other equipment in the factory. If the factory is one using many milling machines there is the most likelihood that there will be a fixture or more for each machine. In connection with drilling and boring operations, there will probably be jigs for use with every machine, or with every type of part to be drilled. It is obvious, of course, that there are numerous types of manufacturing in which neither jigs nor fixtures are used—such for example, as chemical manufacturing of all kinds, and textile manufacturing.

The final kind of equipment to be considered in providing for a factory is that necessary for the maintenance of tools and of other equipment. Repair shops are essential, and these must be suitably located with reference to the shops which they serve. The amount of equipment in the repair shops depends upon the number of machines which it is to care for and the kind of operations involved. It is usually desirable to have small maintenance shops for the following: millwrights,

machinists, pipers, painters, belt-men, electricians, carpenters, pattern-makers.

In all of these problems of equipment, it is of course the particular needs of the particular factory that must be considered. General problems may be discussed in a general way, but after all the margin of difference between success and failure often lies in small things that are peculiar to the individual plant. The rule that is always and everywhere applicable is the rule of ultimate costs. Whatever makes for the lowest rate of expense and the highest rate of output, all things considered, is the policy that will work most successfully in selecting equipment and in all the other problems of production management.

VI

Care of Equipment

THE man behind the machine knows the need of keeping his equipment fit. Many a time have shop foremen had to run machines that they knew ought to be stopped and thoroughly repaired. Shops that have been operated night and day on forced production without allowance for suitable repairs have often suddenly failed to turn out satisfactory or sufficient product.

Keeping the Equipment Fit

Only by constant attention and care in keeping all equipment in the best condition can the highest production efficiency be reached. It is necessary to realize not only that equipment must be kept in repair, but that a certain amount of time must be allowed in which to make repairs. Twenty-four hour operation is not continuously possible for any piece of equipment.

Good foremanship and a regular inspection system are of prime importance in holding the factory equipment up to the highest pitch of production.

First of all, machinery must be kept clean. Dirt and grit may get into bearings and cut them. Water or steam may cause rusting. When a machine must be left idle, it should always be slushed with oil or grease or with some special compound to keep it from rusting. An active machine must be lubricated regularly to prevent wear and excessive power consumption. So, running or idle, a machine must have oil.

So important is lubrication that it is common practise in large factories to have men who do nothing but see that all equipment is kept oiled. Even then, it is desirable to instruct every workmen in the importance of keeping all oil holes and grease cups in his machine fully adjusted, filled, and cleaned. Automatic lubrication should be provided wherever possible.

Operators should be required to report immediately any irregularity of operation or other trouble with their machines. Often small irregularities may be noticed in this way and corrected before serious damage occurs, irregularities that would probably not be detected by the inspector who can spend only a short time at each machine. The operator who works steadily with a machine is the one in best position to know it through and through.

Inspection System

The machine inspection system must be adapted to the character of the plant. It may be possible and desirable to have a daily inspection of all machines. On the other hand, a much less frequent inspection may serve all purposes. It is not wise to depend upon each small shop of a factory to make its own inspection. A centralized control is better.

In one successful inspection system, every piece of equipment is listed by name and insurance-record number on an index card. The inspection interval is determined and recorded on this card, and the card is then filed under the date scheduled for the next inspection. Each day the cards calling for inspections on that date are drawn from the file. A separate inspection card for each piece of equipment to be inspected is then issued. Definite questions on this card call attention to all parts of the machine which are to be examined; and show the inspector exactly what he is to look for. The answers to these questions which can be "yes" or "no" are entered on the card and returned to the head inspector, who issues necessary repair orders. When all needed repairs or adjustments are made, a record of what was done is entered upon the back of the inspection card, which is then returned to the central

office for filing. The next inspection date is then entered upon the machine card and it is filed away under that date. This system insures regular and thorough inspections and follows this up by seeing that necessary repairs are made.

Adjustment for Wear

Adjustments of machines for wear must be made as needed and not only after periodical inspection. The operator, machine adjuster, or repair man must attend to this. Unless the machinery is designed to facilitate such adjustments, an unnecessary amount of time will be lost from production. Some machines have been especially designed for quick adjustment.

It is well to have instruction cards, with illustrations, to show operators how to adjust their machines most quickly and correctly. Such cards should also contain instructions regarding lubrication and safety in operation.

Repairs

When a machine is taken off production, its withdrawal frequently affects other equipment and may necessitate the shutting down of a large part of the factory. For this reason, repairs are often made Saturday afternoon or Sunday, or at night or between shifts. A regular repair gang, having its own repair shop, usually does the work. It is an advantage if the piece of equipment to be repaired can be completely removed from

the production shop—especially if repairs must be made while regular factory work proceeds. It is undesirable to have repair men working in a shop when the shop is in operation upon production.

In some cases, especially where it is common to operate the machinery twenty-four hours daily, as in the case of a paper machine for example, it is of extra importance to repair any breakdown very quickly. Emergency gangs are commonly organized for this purpose. These should have the most skilled men and be provided with all facilities to save time in doing their work.

Planning Repairs in Advance

It is possible to classify the kinds of breakdown which may occur and to plan in advance quick ways of caring for the larger or more common jobs. This will usually require that certain spare parts of equipment be carried in stock ready for immediate use. What to carry in stock as spare parts will be shown by studying the inspection and repair reports on previous jobs.

Where repair work is thoroughly systematized, the tasks are laid out with as much care and forethought as are the regular production process. There is an instruction card showing the standard way of handling the work. Frequently the card shows the

amount of time usually needed for each operation in repairing. A paper mill which used such a system was able to cut down lost machine time from 3 per cent to about 0.3 per cent.

In addition to repairs after a breakdown, or when an inspection shows they are needed, it is well to give equipment a periodical overhauling "whether it needs it or not." This is to get at parts that are not readily accessible and to discover troubles or wear that do not show up ordinarily. Thus, a locomotive has its regular "shopping," and in many mills Saturday afternoon and Sunday are regularly big days with the repair gang.

In spite of the best attention to repairs, depreciation will take place and it is always provided for in the accounts showing valuation of properties. By depreciation is meant that loss in value due to the gradual wearing out of the machine. In estimating depreciation it must be assumed that the best possible repairs are made and that the equipment is kept in good condition by renewal of worn or broken parts.

Depreciation is important in accounting; unless it is recognized and proper allowance made for it, the plant's capital might be paid out in dividends. The plant and equipment gradually wears out, and if it all wore out at

the same rate there would come a time when nothing would be left to show for the capital invested in equipment but a dilapidated and useless plant. To guard against such a condition, the factory accountant figures a certain percentage of the value of the building and equipment for depreciation, and each year sets apart from the earnings a sum to cover this allowance. By the time the machinery is worn out, enough reserve has accumulated in this depreciation fund to purchase new machinery.

Taking Care of Depreciation

The allowance for depreciation is a variable factor. With some equipment the life, or length of time it will render service, may be quite accurately determined; but with other, and especially machinery of new design, the length of life is often a matter of guess work. The Public Service Commissions of some states have established depreciation rates for some classes of equipment. The rates determined by large industrial corporations are also frequently accepted by small concerns as a standard for figuring depreciation. Thus, the annual depreciation of boilers is estimated by the Chicago Union Traction Company as 6.6 per cent, by the Milwaukee Electric Railway and Light Company as 7.5 per cent, and by Stone &

Webster as 5 per cent. Rates are similarly fixed for steam engines, electric generators and machines of various kinds.

Obsolescence

Obsolescence is a form of depreciation which is due, not to wear and tear, but to changes in manufacturing methods or improvements in machinery which render existing machinery less efficient. It is the loss in value which arises out of becoming out-of-date.

Samuel Insull, in describing the Fiske Street Power Station in Chicago, says: "We were able to get 12,000 kilowatt steam turbine generators, so we scrapped the first machines (about 5,000 KW.) and installed the 12,000 KW. units in their places. I think that scrapping operation cost us upward of a million dollars, and I think it paid for itself in about three years owing to the advance made in turbine design." The 5,000 KW generators were not worn out, but because of the development of more efficient 12,000 KW generators they were rendered less valuable. They had become obsolescent.

In any branch of work subject to rapidly changing conditions or development, obsolescence is a possibility that must be taken into account and proper allowance made therefor.

A machine that is temporarily out of ser-

vice, while others of similar type are being run, is especially liable to depreciation due to its being robbed of parts wanted for use on the other machines. This practise would be unnecessary if spare parts were always on hand and easily obtainable, but frequently it does not pay to carry spares for every part.

Machine Stripping

To shut a machine down because of a broken part, when that part can be replaced from some similar machine that is idle, would appear to be poor management under the circumstances. However, machine stripping should be indulged in only when working conditions demand a quick repair. When a part is taken from another machine, an order should be entered at once for its replacement. In some shops machine stripping is a habit, and it cannot be condemned too strongly as a bad habit. To guard against the growth of such habits it is wise to remove idle equipment from the shop floor and lock it up where it can be reached only on proper authority.

For insurance records, the position of every piece of equipment must be recorded. When a machine is removed from a shop to storage, or from one shop to another, the record of location should be corrected. This is a matter that requires extreme watchfulness if the

records are to be kept accurate and the insurance is to be safeguarded. To insure this, equipment should be moved only on an approved order, a copy of this order being sent to the person who keeps the records of location.

The Tool-room

Many factories have a tool-room for the care and making of tools. While the practise varies in different factories, it is common to refer to the tool-room as the place where tools are made, and the place where tools are stored ready for issue to the shop is called the "tool-cage" or "tool-crib." The tool-room for the production of tools may be organized as a regular shop or department of the factory and managed in a similar way. The tool-cage is a tool store-room and frequently is equipped with machines for re-dressing or repairing tools which have been used.

It is now recognized in many factories that tools should be prepared for use by a specialist only and in accordance with standards which have been carefully determined. It makes an important difference how tools are ground or made ready for use. The old practise of each man grinding and caring for his own tools is generally considered inefficient, as it permits of much waste of time and varying standards of treatment. Tools should

be made to predetermined gauge and specifications. When it is impossible to finish the tools in the shop where they are made, they may be prepared for use in the shop where they are used; but this should be done by specialists rather than by the machine operator.

A tool is inefficient unless used as intended. To insure this, instruction cards are drawn up to show the workman exactly how the tool is to be used. Where time-studied rates are in use, this instruction card will also show the speed of machine and all other details of the operation to be performed.

Tool Accounting

As tools represent a large investment of the plant's money, it is important that they be carefully accounted for and accurately charged against that part of the production in which they are used. Tools may be divided into two classes: (1) those which are consumed or worn out in connection with a given contract or production order, and (2) those which are used over and over again on various orders or in maintenance and repair work. The tools which are consumed on one production order are charged out as issued from the store-room. This charge may be made direct to the production order or may be made against the shop expense account or overhead. All that

is necessary to get the charge recorded is to pass the requisition calling for the issue of the tools to the proper accounting department.

Tools which are used on miscellaneous work, such as wrenches, hammers, or in fact any that are not worn out on one order, are commonly issued to the various shop tool-cages and carried on the tool-cage account. This class of equipment is often charged one-half to the expense account when purchased or when issued from general stores.

The tool-cage attendants are responsible for maintaining the tool supply issued to the tool-cages. For this purpose some accounting system is needed to keep track of tools loaned. Tools worn out or broken are returned to the tool-cage. If broken through carelessness it is sometimes required that the employee pay for them. Broken or worn-out tools are replaced by requisition on the general store-room.

Keeping Track of Borrowed Tools

A brass check system of keeping track of tools is common. Each workman has a supply of brass checks bearing his number. Every time he borrows a tool he leaves one of these brass checks at the tool-cage. The check is put in the place of the borrowed tool. By this method it is possible to tell who has any tool—though

it is not easy to tell how long the tool has been out, or how many tools any one man has.

The double-check system shows not only who has the tool but also the number of tools a man has out. In this system the workman is given a number of round checks. On a board in the tool-cage opposite his name and number are hung a similar number of square checks. There is also an empty hook. When a round check is presented for a tool it is placed on the empty hook opposite the man's number and a square check is removed and put in place of the tool given out. Thus, at any time the number of round checks on his hook shows how many tools a man has, while the square checks in each tool space shows that he has that particular tool.

To keep account of the length of time tools are out it is necessary to make a written record of some kind, as by filing a receipt. This takes time and is not widely favored.

When a number of tools are needed at one time it is a good plan to determine in advance what these should be for the work to be done and record the names and quantity on a tool list. Then the tray is issued with the full set of tools on one check.

The tool cost for a shop may be considerable and the production efficiency may be greatly affected by the condition of tools.

For this reason it is well to have the tools issued in as nearly perfect condition for use as may be possible. If the workman has an instruction card telling how best to use the tools, he must be made to follow it. If no instruction card is used the gang boss or overseer should see that the workman is properly instructed. Many good tools are spoiled by carelessness or failure to watch the work being done. Records should be arranged to show the length of tool life, and if the wear and tear seems excessive the matter should be investigated.

Tool Care

The task of determining what is the best tool to use and how best to care for it should be given to a specially competent tool man. He should analyze the tool carefully and check his conclusions by carefully made experiments. He should prepare instructions for the use and care of the tool. The time and money spent in this way are well repaid. They not only save tool cost, but they save material through reduction of spoiled work, and they directly promote production efficiency.

VII

Material

MATERIAL has value chiefly in proportion to the labor that has been spent upon it. The crude ore in the earth or the standing timber in the forest has only potential value; it becomes useful and acquires real value only after man has applied labor to change its location and form. In the case of iron and steel products, for example, the ore must be searched out, miners must bring it to the surface and prepare it for transportation, railroads and steamships must transport it, and factories transform it into the finished product ready for use. So the products of manufacture consist of goods upon which labor has been performed to transform raw materials either chemically or physically into articles of higher value.

Adding Value to Material

The quality and value of a product are closely related to the quality and value of the raw materials used. The product must be more valuable than the raw materials as a whole else there could be no profit in making

it. If the raw materials are of poor quality it is difficult or impossible to make a high-grade product. Cheap leather will not make good shoes. Poor lumber will not make good furniture. Faulty steel will not make reliable watches or automobiles.

Classes of Material

There are several classes of material used in manufacturing. That which enters into and becomes a part of the product is called "direct material." That which is necessary but does not become a part of the product is called "indirect material." In making brass articles the brass is direct material. The sulphuric acid and soda used in washing and brightening the brass are indirect materials. Similarly, oil, waste, emery, and the like, are indirect materials.

Another class of materials is called "supplies." These are articles upon which no work need be done, but which are used (1) in assembling a finished product, or (2) in maintaining the plant. Thus, clocks, speedometers, and horns may be classed as supplies by an automobile maker—they enter into the final assembly. Likewise, files, emery wheels, brooms, stationery may be classed as supplies—they are used in maintaining the plant.

Different classes of material are often

handled in separate store-rooms. Materials are frequently classed according to value and volume and stored accordingly.

Handling Materials

Differences in bulk and character make the problem of handling materials a varied one. Bulky materials like coal, ore and ashes are usually handled by gravity or conveyors. Railroad trestles are much used with drop-bottom cars for unloading. As compared with shovelling out material from cars, the trestle plan costs about one-fifth to one-seventh as much. Where conditions prevent the use of a trestle locomotive, cranes with grab-buckets or travelling scoop conveyors are used.

Fluids, such as fuel oil and asphalt, are best handled by pumps and pipe lines if used in any quantity.

Heavy steel plates and shapes, such as are used in bridge and building work, are easily handled with overhead girder cranes. Sometimes a magnet is used for quick pick-up and to save the labor of adjusting chains around the work to be moved. Other devices for handling bulky materials are Gantry cranes, steam shovels, and belt conveyors of various types.

Package materials are cheaply handled by gravity conveyors or travelling belts. The hand truck is a last resort only. There are

many devices in the conveying and elevating line to save time and cost in handling material. The Revolvator is a handy device for conveying, elevating, and stacking barrels, boxes, and bales of material.

How Much Material for Stock?

To handle the material supply to advantage, it is important to know the maximum and minimum amounts likely to be on hand at any time. This must be determined in such a way as to insure against running out of material, while getting along with the smallest possible stock. The minimum stock must be enough to keep the plant supplied from the time the requisition is written for a new supply until the new supply can be delivered and made available for use. This time may be recorded as the standard delivery time and should be revised often enough to keep it accurate. The standard time multiplied by the rate of consumption of the material, which should also be kept up-to-date, will give the minimum stock to carry. To determine the rate of use study past material records or maintain a plotted curve of amount used per week.

Suppose, for example, that it requires six days to get a certain material delivered, and that the daily rate of consumption of the material in the factory is 1500 pounds. Then

the minimum stock to carry is arrived at by this calculation:

$$1500 \times 6 = 9000 \text{ lbs.}$$

It would not be safe to allow the stock to fall below 9000 pounds, since this is just enough to keep the plant running while a new supply is being shipped. The moment the stock on hand approached 9000, an order should be placed for a new supply.

The maximum stock to carry on hand is governed by the rate of use and by the amount which it is economical to purchase or ship.

Certain materials are subject to special conditions—coal, for example. Where coal can be most cheaply received by water transportation, and the harbor is subject to ice, the winter's coal supply should be accumulated during the summer, as is the general practise under such conditions.

In buying any materials, it will take longer for delivery if the order is a new order. The best delivery conditions are obtained when the material supply is contracted for six months or a year at a time, with specified dates for deliveries. It is important that the factory and sales departments cooperate to determine the future monthly production requirements. Then material may be purchased and scheduled for delivery far ahead,

requiring the carrying of a relatively small stock.

Frequently material is something that is itself the product of manufacture. Metal castings, for example, are bought from a foundry, and in this case must be made from patterns supplied by the purchaser. How are these patterns cared for? If certain castings are regularly obtained by the year on a contract basis, patterns will be retained at the foundry with an arrangement whereby the foundry keeps them in repair. If the castings are purchased at irregular intervals and of different foundries, a pattern order is usually issued at the time of writing the purchase order, the pattern is made—or if already made, is inspected and made ready for use—and sent to the foundry. When the castings have been completed, the pattern will be returned with them. The receiving records should be checked to insure that patterns are returned.

Handling Patterns

To insure quick finding of needed patterns, a store-room is usually provided where they may be put away and indexed. A card file shows name, number, and character of patterns, and place of storage in the pattern store-room. When patterns are sent to the foundry the record is entered on the cards and

duplicate card records are placed in a special file showing which patterns are out. These records are checked up as patterns are returned.

Standard Specifications

So far as possible, all materials used should be in accordance with carefully prepared specifications. These specifications should be established as standards. Then questions which arise regarding the quality of materials may be settled by comparison of the actual quality with the specifications. In using materials difficulties are often encountered which may be due to the method of treatment quite as much as to faulty material. By keeping the material strictly up to specification one may the more confidently run down faults in the processing. If it is found that the material is unsuitable the specification should be changed.

In purchasing many materials it is the custom to buy them by trade name and not by specification. This is a practise that will serve fairly well in many cases but it does not guarantee against possible changes in the quality of the material and it is unfavorable to competitive buying. As an example, consider the buying of tool steels. There are innumerable brands, each of which become known to the men in the shops by name and they come to believe that only one certain

brand will do for this or that tool. This, of course, is seldom the truth.

When Admiral Caspar F. Goodrich was commandant of the New York Navy Yard, he was amazed at the vast number of varieties of tool steel that were demanded by name or brand, with in every case a certificate stating that none other would serve. He consulted Frederick W. Taylor, who advised him to buy steel according to specification, and assisted in preparing specifications. These were adopted for use in the Navy Department. The first high-speed steel that was bought under Mr. Taylor's specifications was for the gun works at Washington. Steel formerly purchased had cost $1.25 per pound, but under the specifications steel was bought at 32 cents to 36 cents a pound, and the new steel did about $33^1/_3$ per cent more work.

By purchasing tool steel in accordance with specifications, by classes, it is easier to decide what steel to use when a substitution must be made for some brand that is out of stock. A trial of other steels in the same class is almost certain to lead quickly to the selection of a suitable substitute. The same facts apply not only to steel, but to almost every kind of material.

In preparing specifications, it should be kept in mind that materials will be inspected

for acceptance in accordance with the provisions made. Tests should therefore be provided which will quickly indicate whether the material is to be accepted or rejected. Only matters of real importance should be included in the specification; the inclusion of some trifling requirement many times causes a considerable increase in price. The preparation of specifications should be in charge of a specialist and changes should be authorized and made effective only through that channel.

Materials as Assets

The investment in raw material stores is likely to be large. This, in spite of care in holding stock down to the smallest minimum with which one can run and still be sure of having the material when needed. It is better to have the materials on hand in the form of raw material or finished stock than in the form of partially processed work. And of all forms, the raw material is to be preferred as it would have the best sale value in case of any emergency, since it may be presumed that it could be used by others. Work in process is likely to have no value whatever except as a part of the ultimate factory product. In many cases it would be expensive to convert it to other uses; in the event of failure of the company, work in process would have only

scrap value. Finished product can usually be sold at some price even at a forced sale, but it is bad manufacturing policy to accumulate more finished product than needed to care for actual trade in sight—unless the product is firmly established in its market.

Guarding Materials

While a few dollars in the cash drawer are guarded with the greatest care, it is not uncommon to see materials in all stages of production handled with the utmost disregard of their value. Materials are left exposed to the weather, are scattered in various unprotected places, and frequently little record is kept of their value or condition. Often one sees in a manufacturing plant various articles around in odd corners, such as old machines, pulleys, machine parts, and fittings. Such scrap, which frequently is kept because of some possible future use, should ordinarily be turned into cash and thus made available for practical use.

There should be a place for everything and everything in its place. It is a good plan to have a record on the spot showing what and how much of a material is on hand. Storage places which are regularly provided are more likely to give protection against loss or deterioration than if materials are scattered or placed wherever convenient at the moment.

Coal should not be left exposed to the weather to collect snow and moisture to be later melted out in the furnace at great loss. Metal articles should not be allowed to corrode. When materials have once been received at the plant it should be the special duty of someone to see that they do not deteriorate and are not wasted.

Care will naturally be exercised to see that all material bought and paid for is received and is in the condition which it should be. When shipments are in car-load lots, there is always the possibility of losses in transit even if original weights are correct. It is necessary to see that goods received check up accurately with goods purchased.

Handling Materials

Careless handling wastes many dollars in the course of a year. Rolls of paper may be dropped on the floor in such a way as to crush the edges and spoil many outside layers. Bulk materials are often spilled in trucking so they can not be recovered. Broken boxes and barrels cause losses. Unless material is of very great value the average workman will use little care in protecting it against loss. The far-sighted foreman can save dollars for his company by educating his men aright along these lines.

Work spoiled during the manufacturing

processes may run into large amounts. In some factories "scrap" has been known to run as high as 30 to 40 per cent of the work begun. In almost all factories where there is much handling of the work, an important saving can be made by giving attention to educating the employees in this regard and insisting upon a high percentage of good work. This is a profitable field of exploration in search of increased production. Neither material nor labor should be wasted; but one or both are lost where scrap work is produced, and in addition the productive time of the machine is wasted.

A fruitful cause of spoiled work is too much speed. High speed is not efficient if it results in ruining a good part of the raw material. The most economical production speed should be determined by investigation. It has often happened that a reduction in speed of operation has resulted in an increase in useful production.

Additional waste occurs in materials which do not directly enter the product but which are of an auxiliary nature. Cleaning, polishing, or lubricating material needs careful watching if it is not to be used to excess.

Materials which do not enter the product are called "indirect materials." Insofar as these are bulky or are used in relatively large

amounts, they are bought and handled in the same manner as "direct materials." Where relatively small quantities of materials are used, as in the case of cotton waste, sand paper, emery cloth, files, it is well to issue them from the tool-cages as needed. In some cases it is possible to establish a budget system by which the amount of such material issued per day or per week is limited. Thus in the case of cotton waste used in the machine shop or engine room a certain number of pounds per person per week may be allowed. Such a system has been known to result in savings without any inconvenience whatever.

Budgeting Indirect Materials

Supplies are almost always issued from the stock-room on written requisition. One class of supplies consists of finished parts that are used in the final assembly of the product. The plan of work should show how many are required per unit of product, and requisitions should be issued to provide only that number. In case of breakage the replacement would be made on a special requisition approved by the shop foreman.

Another class of supplies consists of those used in the shops and offices in routine work, such as brooms for sweeping, oil cans, lamps, stationery and forms, blank books,

pencils, and the like. These should be issued on requisitions, and records kept of the amounts used by department or shop so that any excessive consumption will be evident at once.

Handling Supplies

All materials and supplies should be under the care of the storekeeper in orderly storerooms. Records should be kept showing what is used and the rate of use and other information needed to enable the store-keeper to maintain proper stocks. Every article or item used should be recorded and listed on a regular "list of articles to be purchased." This list is for the use of the purchasing department, which can consult with the storekeeper on what is required in the way of orders and get such information as will permit of buying to the best advantage.

VIII

Purchasing, Packing and Shipping

THE work of procuring materials is quite as specialized and important a function in factory organization and operation as that of securing the labor or providing the machinery. Usually there is a special purchasing department which has charge of this work—though in a small industry the general manager or some other official may combine purchasing with other functions.

Four steps are involved in making a purchase. These are:

1. Determining what is needed.
2. Preparing the specifications.
3. Selecting the concern from which to purchase.
4. Placing the order.

The Purchasing Organization

Many dollars may be saved or wasted, depending upon how well these duties are performed. In most cases other departments than the purchasing organization determine what is needed and prepare such specifications as are used, leaving only the last two functions to be per-

formed by that department. In any event, the purchasing department, or purchasing agent, should insist upon having a specification that will leave no question unanswered regarding what is wanted and one that will also permit of buying to best advantage.

One of the purchasing agent's chief duties consists in finding where the goods may be bought and in deciding to whom to give the order. By following the market and his records he knows when orders should be placed. For use in this connection there should be well-kept files with classified information of sources of supply, of former purchases, and of quotations and discounts received. A file should be kept of catalogs received and this should be indexed by a double card system—one card filed by name of article and the other by name of seller. The catalogs themselves may be placed on numbered shelves to suit their size and type.

A record of former purchases is conveniently kept by having a good-sized card for each material on which to enter data from quotations and purchase orders. Such a card will show prices paid, date of purchase, and time required to secure delivery of the material—or it may give reference to the filed copy of the purchase order which will show deliveries received.

The purchasing agent should be familiar with the processes of the factory which he serves. He must keep informed on market conditions and prices, by following trade papers and by talking with sales representatives. He should know something of the cost of production of the articles which he buys and compare prices with this cost. He should also know the points of origin of his materials and follow the news of these localities, as by so doing he will often obtain knowledge on which to act to the profit of his company. Factors affecting the supply, ease of transportation, and demand for a material, should be watched for first signs of changing prices.

Delivery Time is Important

In many cases delivery of the material in short time and absolutely as promised is of equal importance with price. Sometimes it is of greater importance. In bargaining for deliveries the purchasing agent should have knowledge of what is possible and of the ability and desire of the seller to live up to promises. He should know as much as possible about the concern from which he buys; seemingly insignificant information often becomes of great value in guiding his dealings.

Where purchases are made on the basis of cash, discounts are frequently allowed. A good saving can be made by taking cash dis-

counts, and it is usually good policy to do so; but it is sometimes of financial advantage to be able to buy for deferred payments. Conditions may be such that the company cannot put large sums of cash in materials, and credit purchases become a real help. The buyer must be fully posted regarding the financial condition and policy of his concern.

Specializing the Functions

In large factories the purchasing organization is frequently a large department. In such cases the purchasing agent may have several assistants, and the work may be divided according to class of material handled or according to function performed, or both. One man may keep track of material requirements and market conditions and keep posted as to the most favorable time for purchasing; another may look after the actual placing of orders, filling in forms and maintaining office records; another may follow up purchases and see that deliveries are made as scheduled; while still another may supervise inspection of goods as received and pass upon invoices for payment. It is well to have the traffic man closely associated with the purchasing department, to route shipments, check up the receiving clerk's reports, handle claims for shortage and damage, and approve freight and express bills.

In a smaller plant one man and a clerk may do all the buying; but it is a mistake to neglect any of the important functions of a purchasing department simply because an establishment is small and is unable to have a full-fledged department. The very fact that the plant is small should make it easier for the purchasing agent to maintain his records up-to-date and keep informed on the various phases of the work.

Centralized purchasing has been universally proven the best policy. For this reason it should be a rule that all business relating to purchases be done through the purchasing department—whether it be a department of one man or a dozen. Inquiries as to prices, time for delivery, catalogs, or any information that has to do with purchases should be asked for through the purchasing agent, whether or not a purchase is contemplated at that time. No purchases, however small, should be made except on authority of the purchasing agent, and no goods should be received into the plant except through the regular receiving station. A close adherence to this rule is of great importance and makes for the convenience not only of the purchasing department, but in the long run of all concerned.

The position of the purchasing agent of an

industrial plant is much different from that of a buyer in a mercantile establishment. In the latter the buyer decides what to purchase, but in the industrial plant it is almost always the case that others decide what is needed and call for it by requisitions on the purchasing department. In some cases all requests for materials will be made upon the store-keeper who issues requisitions for their purchase if he does not carry them in stock.

What to Purchase

The quality of material to be purchased, especially if of a technical character, must often be determined by reference to someone having the necessary special knowledge of requirements. The purchasing agent can often save money by recommending for consideration other materials or qualities which might be used to advantage. This experience will sometimes indicate what not to purchase, as complaints regarding materials which fail to give satisfaction reach him and will be remembered. Changes in personnel often result in requests for the purchase of goods which previous experience has shown unsuitable.

Many different classes of goods are offered to the purchasing agent from day to day and it is his duty to determine which of these require consideration or should be referred to factory officials for decision. So, even though

goods are purchased only on requisition from some source in the factory, the purchasing agent must make frequent decisions regarding what to buy.

Where to Purchase

In getting supplies for your personal needs, you are accustomed to buying clothing from some particular tailor or dealer. Probably you also buy your shoes at a certain store and your medicines at a favored drug store. Why? Not because you get the lowest price in every case, but because you get the quality of goods that suits you, with prices that you consider fair and service that pleases you. The terms or credit arrangements meet your financial condition.

You have found advantage in confining your buying to a few dealers for each class of goods. Exactly the same conditions affect a manufacturing concern in making its purchases. Regular customers receive the best service. In case of shortage of material the preference on deliveries will go to the regular customer. If some special service under difficult conditions is needed, the natural course is to apply to the company which gets the bulk of your trade rather than to a stranger. Good will, established relations, reputation —these are all factors in deciding where to buy, as well as price.

The purchasing agent must take the ini-

tiative in deciding when to purchase. Many opportunities to buy at favorable prices would be lost if he waited until the stock became low and requisitions come through. An impending shortage in the market or conditions tending to cause high prices must be anticipated by the purchasing agent, if possible. Indeed, his success depends upon how well he judges his market in these respects.

When to Purchase

It is of the first importance to care for the monthly and yearly needs of the plant at the best prices, but loading up with an excessively large stock because of what appear to be specially favorable prices is dangerous speculation. A large iron mill owner who had followed this sort of speculation in his raw materials for many years reported that he considered himself lucky to break even on his operations. He concluded that it seldom paid to purchase goods much before they were needed, even if prices looked attractive at the time. It is, of course, impossible to avoid an element of speculation in buying, but this should be reduced to as scientific a basis as possible.

Purchases may be grouped into classes.

1. There are those materials regularly used in large quantities and for which contracts may be made by the year, as in the case of

iron ore for a blast furnace, copper for a brass mill, tires for an automobile factory, leather for a shoe factory, and the like. These contracts would commonly call for definite amounts with deliveries either specified at the time of purchase or from time to time at sufficient advance over time of delivery.

Methods of Buying

2. Another class of contracts requires that full requirements of the factory for a year be purchased from one concern, neither the quantity nor the delivery being specified. Special discounts on a sliding scale are given in connection with such contracts. Electric motors or similar supplies might be purchased on this plan.

3. Other purchases consist of miscellaneous materials bought from time to time for delivery in one lot at a specified date, or for delivery in several lots as scheduled. Purchases made well in advance of requirements with carefully scheduled deliveries to meet the factory needs will permit of carrying the minimum amount of stock. George D. Babcock, formerly of the H. H. Franklin Company, reported running the automobile factory with as low as 11¼ days' supply of stock without detriment either to production efficiency or to costs. This was made possible by having a definite schedule of deliv-

eries which the purchasing agent insisted must be lived up to exactly. Few concerns approach so good a record.

Emergency purchases of goods wanted in a hurry may be made without taking time to get bids, by placing the order with firms of proved reliability. In no case, however, should the order be placed without a price being agreed upon—even though it must be obtained by telephone or telegraph and, in a last resort, be estimated.

James M. Dodge, late chairman of the board of the Link-Belt Company, said more money was lost by purchasing agents through delays in getting materials when needed than was saved by taking time to get competitive bids. Even if the orders "blew out the window" and were filled by the first man to pick them up, the price could not be more than when purchased of the lowest bidder at the cost of a delay that shuts down a part of the plant. In making contracts for large amounts of material or a year's business, time enough may be taken to obtain the best possible terms consistent with the material and service required. In making emergency purchases, a telephoned price from a firm of proven reliability is sufficient and in almost all real "emergencies" will prove much cheaper in the long run than any plan which involves delay.

Receiving the Goods

Notice of shipment, bill of lading or invoice will be received at the time goods purchased are shipped. If important, the traffic department may trace the shipment all the way to the plant. When the goods arrive, the receiving clerk is notified by the railroad or persons charged with delivering the goods. He then issues instructions for their disposition, for the spotting of freight cars alongside the plant, and other traffic details.

A report of goods received is made out and checked with copies of the purchase orders. A copy of the report is sent to those interested, who may be the plant superintendent, the one who is responsible for inspection and testing of materials received, the store-keeper, and the purchasing agent. It is important that all persons concerned be promptly advised of the arrival of materials. No materials or purchases should enter the plant without passing through the receiving station and being properly recorded.

Passing the Invoice

Goods purchased must be paid for promptly if advantage is to be taken of cash discounts. The invoice, or bill for the goods, with the bill of lading showing shipment has been made, will be sent to the purchasing agent for checking with purchase order. He will then author-

ize payment and pass the invoice to the accounting and disbursing department. If the discount is to be taken, a check will be sent at the proper time.

In some cases, the purchasing agent sends a separate notice to the receiving clerk to cover each separate purchase or invoice. When the goods arrive this notice is checked and approved by the receiving clerk and then forwarded to the accounting department where it is pasted upon the back of the invoice and filed, thus completing the record of the purchase.

The routine followed in various plants differs, of course. The outline given in the foregoing paragraphs indicates the various functions to be performed. These may be accomplished in such way as best suits the local plant conditions.

It often happens that claims must be made for goods lost or damaged in transit. This is generally cared for by someone who specializes upon traffic and claims.

Packing and Shipping

Damage to goods often results from improper or careless packing. The shipping department of a plant might learn much regarding the packing requirements by studying shipments received in bad condition.

Only by realizing how goods will be handled—or rather mishandled—in trans-

portation can one appreciate what is required in packing. One should make sure that goods will arrive in the best condition. The boxes, barrels or crates used should be so substantial that such shocks and drops as they are sure to receive will not break them. The material inside must be protected against damage from such handling. This fact seems so obvious that it is hard to understand why so many poorly packed shipments litter the freight sheds.

Making the Package Pleasing

If goods must be transported by men or pack animals, they should be put in small enough packages to permit such handling. The convenience and preference of the customer should be consulted. The slogan "We could not improve the goods, so we improved the package" carries a hint for many shippers. The purchaser is interested in the style of package he receives, whether he buys a stick of shaving soap or a crate of machinery.

All work completed by the factory and ready to ship ceases to be a responsibility of the factory. On the books of the company it is charged to "finished stores," and the factory is credited with having supplied this additional stock for sale or delivery to customers. No goods should be shipped unless they have passed through the stores.

The shipping department should receive a copy of every order with full information regarding what to ship, how it is to be packed, and the route for the shipment. The store-keeper will be advised of the shipping requirements, either by a copy of the order or by requisition from the shipper. When the goods are ready he will notify the shipper. After the goods are assembled ready for packing—or at some suitable time during the preparation of the shipment depending upon the character of the goods—an inspector will check the goods with the order to insure that the quality and amount are as ordered.

The shipper must see that the goods are packed in such a way as to secure the most favorable freight classification. Cars must be loaded so as to prevent damage from shifting of goods. Wherever possible, goods are shipped in carload lots; the carload rate is cheaper than the less-than-carload rate. To gain the advantage of carload rates, goods destined to different towns in the same general territory may be shipped most of the way in one car to a convenient transfer point and then go the balance of the way in less-than-carload lots. Before leaving the plant the goods should bear clear and complete shipping instructions.

Although most sales are f.o.b. cars—that

is, carted and loaded free on board cars at shipping points—it is sometimes requested that goods be shipped with freight prepaid to destination. It is to the advantage of the shipper to ship f.o.b. factory with freight allowed to destination, as in this case his responsibility and liability end with delivery of the goods to the railroad. In the other case, where freight is prepaid, the shipper is responsible for safe arrival of goods at destination. Should the shipment be lost or damaged and it be necessary to collect claims from the railroad, he would then have to do this instead of the purchaser.

F. o. b. and Prepaid Shipments

Orders filled by the shipper must be turned over to traffic or billing clerks to record bill-of-lading data and to make out bills. Complete reports must be kept by the shipping clerk of every shipment. No goods should leave the plant except through the shipping room. Many dollars' worth of goods may be lost unless the shipping department is thorough and careful in its work. Goods purchased must be carefully checked before being received into the raw material and supply stores. Goods taken from finished stores must be carefully recorded in making shipments. Both incoming and outgoing materials must be watched to protect the company from loss.

IX

Stores

IF material is not in process in the shops, or about to be processed very shortly, it should be in a store-room in charge of a store-keeper. The stores department is ordinarily organized to take this responsibility.

Stores Organization

The "raw material stores" should receive all incoming material which is to be used up or transformed in the factory processes. Materials which have been completed so far as one shop or operation is concerned, but which may later have more work done upon them or which may be used in a final assembly, should be placed in the "worked material stores." Supplies used in the factory or in final assemblies—that is, goods which are used as purchased—should be in the "general stores." When there is a surplus of unfinished work it should be removed from the shop to a "work-in-process" store-room. Product completed and ready for sale and shipment should be in "finished stores."

Each of these stores may be sub-divided as conditions require. Thus, there may be separate stores for iron and steel, separate stores for leather, and so on—each a store-room by itself with its own staff.

It is good management to have all stores under the control of one general store-keeper. A large stores organization would include a bookkeeping division, stock-keeping division, move gang, transportation service, and a shop for cutting stock. In some cases the bookkeeping or record-keeping division is a separate organization. The salvage department, which looks after the utilization of spoiled parts or wasted materials, can well be included in the stores organization. In this way, all material of whatever class which is not in the immediate charge of the shop foremen for processing purposes, is cared for by the storekeeper and recorded on the "balance of stores sheets."

Stores Construction and Equipment

In following out the policy of efficient routing, by which all unnecessary travel of material is avoided, it may not be possible to have one central storage building. In fact, all material can not be cared for in the same way; coal, for example, must be near the power plant and handled in one way, while finished product may need to be handled quite

differently. In a structural steel works, with straight-line flow through the plant, the raw material in the form of steel shapes is unloaded under girder cranes at one end of the plant, finished product is loaded onto cars at the other end, and the general supply room is somewhere between. Nevertheless, there is advantage in grouping as much of the stores as possible in one building or storage point.

If the building is constructed especially for stores use, it will usually be made fireproof, and can be planned to have bays for the erection of bins. The original plans may also include industrial tracks, overhead cranes, or monorail cranes and conveyors for efficient handling of material. If bulky and heavy packages, like large paper rolls, are to be handled, the building may be arranged so that freight cars can be run in under an overhead crane, which will unload the cars and put the material in its proper storage place at one operation. For the storage of material like grain, chutes and conveyors are arranged to avoid any but mechanical handling of the material.

Some materials, like coal, may be stored in the open—though it usually pays to put coal under cover. Even when material is stored in the yard in the open it is well to provide bins to hold loose materials, cradles to hold

bar stock, and similar arrangements for keeping the material in order.

Some classes of goods require special provisions for their preservation. For example, certain food factories require refrigerated stores; some paper and tobacco factories must have store-rooms with humidity control, while others require careful temperature control. Efficient production requires care in the handling of material whether in stores or in process.

Bin Arrangement

As a convenience in handling and keeping a record of materials in stores, it is common to construct bins of suitable size. These may vary from the size of a cigar box to that of a grain elevator, depending upon the character of the goods. Bins for the storage of certain small supplies, tools, and the like are often made in standard unit sizes which may be easily sub-divided. One design in general use consists of a series of bins, two wide and eight high, each bin 24½ inches square by 18 inches deep. This has been found to subdivide most conveniently.

There are now on the market many different forms of unit sectional stores bins and shelves made of steel. These have the advantage of being fire-proof and are easily assembled into any size desired. They are

naturally more expensive than wooden construction as they are more permanent. In some instances, ordinary packing cases, piled one upon another, serve quite as well as any other form of bin. Whatever type of equipment is used, the arrangement should be orderly and adapted to the kind of classification.

Where much material is stored a double bin system is sometimes used. Material must be completely exhausted in one bin before any is withdrawn from the second. Such an arrangement gives an automatic warning when stock begins to get low. Where large stocks are carried it is sometimes necessary and convenient to have a surplus stored in a larger or master bin. This master bin may be in a separate warehouse.

Bin tags are used to record the amount of material in the bins. When a master bin is used, a master bin tag should be placed on the regular bin with the regular bin tag. This master tag should show the location and amount of the surplus supply. As this supply is drawn upon to replenish the regular bin, the record must be corrected upon both tags. It is an important part of the stock-keeper's job to see that the bin tags are correctly filled out and that the amount of stock on hand agrees with the record upon the tag.

Handling Stores

Where the equipment for handling and storing is adequate, incoming materials are soon unloaded and placed in stores. Prompt unloading is essential, and goes hand in hand with careful scheduling and prompt deliveries. If, after material is delivered on time, it is allowed to stand unloaded in cars, the end sought is defeated. Moreover, such delays add extra expense in the form of demurrage charged for cars or vessels held longer than the time allowed.

Care should be exercised in putting materials into stores. The permissible unit load upon floors, wharves, and elevators must not be exceeded. Coal liable to spontaneous ignition must not be stored in deeper piles than is known to be safe. Goods must be so placed as to be accessible when wanted without rehandling other stock.

It is also wise to maintain a regular turnover of all stock. If new stock is stored in such a way that it will be withdrawn before using up what remained of the former stock, this older stock may deteriorate and eventually become of little value. It is better to place material so that it is used up in turn. In some classes of work this is particularly important as applied to "worked materials" and "work in process." Minor changes in

manufacturing conditions may creep in and make it difficult after a while to use material that has been overlooked. Moreover, when changes in manufacturing methods or changes in product are to be made, it is well to consider the materials in stores and arrange to use them up before the changes are made.

The Use of Symbols

In classifying materials for handling and recording, it is an advantage to use symbols. The symbols serve as standard abbreviations in written records, insure the use of one name only for the material, and assist in storing and finding goods according to classification. Each kind of stores should have its own classification after some logical and easily-remembered plan. The symbols should be such as to avoid conflict or confusion.

Numerical symbols are sometimes used. In this system each class of article is given a number. A disadvantage here is the fact that there is nothing to assist the memory in recalling the symbol. One must refer to the classification lists frequently in entering the less common materials.

The so-called Mnemonic system overcomes this difficulty by making the symbol of the initial letters of the material. Thus, in a symbol consisting of three letters the first letter might be S for Steel, the second letter

T for tool, and the third letter R for round; giving STR, meaning round tool steel. This symbol may be preceded by another to indicate the general class of stores, as SV-STR which is interpreted: classified stores (S), for a variety of purposes (V), round tool steel (STR).

When a letter system is used, materials are arranged in stores in alphabetical order, but with the most-used stock put in the most accessible positions. Store-keepers soon learn the symbols and can quickly put their hands on any material requested.

The Salvage Department

In many factories there are certain classes of material that are likely to be neglected, such as waste materials, discarded machinery, old lumber, used cotton waste. It is generally profitable to have a salvage department to look up all such material. This department should have a shop of its own where these materials may be collected and put into the most valuable and salable condition before they are turned into "salvage stores." Oily steel chips from metal cutting operations may have the oil separated and made usable. The chips may be classified by kind of steel and in this form bring a better scrap price. Soiled cotton waste may be washed and re-issued for use. Old papers may be baled for selling. In a large plant

the savings effected by the salvage department may amount to as much as $100,000 per year, and in any plant the amount saved will be considerable. By having a special department for salvage work, wastes that would otherwise be neglected are recovered and turned to profitable account.

The Perpetual Inventory

Modern stores records are kept on "balance of stores sheets" in the form of a perpetual inventory of materials. If properly kept and checked it is possible to tell at any time the inventory value of materials, this requiring no more time than is necessary to draw off the figures from the various balance sheets and total them.

A balance sheet is used for each material carried in stock. At the top of the sheet is noted the minimum amount of material to be kept available for use. When the quantity available falls to this minimum it is time to issue a requisition for more, the amount to requisition being shown at the top of the sheet. When the requisition is written, the amount and date are entered in columns under the heading "stores ordered, but not yet delivered." When information is received from the purchasing department that the material has been ordered, the purchase order number and date set for delivery are also recorded. The date and quantity ordered are then

entered in the column under the heading "stores available." When the purchase arrives, new entries are made. Since the order has now been delivered, the quantity is deducted from the total in the column "stores ordered, but not yet delivered," and is added, with date, in the column "stores on hand."

In setting aside stores for use on a particular job, the amount apportioned and the date are entered in the column "stores apportioned to an order but not yet issued from store-room," and this amount subtracted from the column "stores available." When the stores are actually issued and pass from the store-room to the workroom the amount is subtracted from the columns "stores on hand" and "stores apportioned."

What the Perpetual Inventory Shows

Thus, the balance of stores sheet shows at any time the exact standing of stores. It shows (1) stores ordered but not yet delivered, (2) stores available, (3) stores on hand, (4) stores apportioned. Every time stores are added to or subtracted from any one of these groupings, the change is entered at once on the sheet. So its record is always up-to-date—a sure index of the condition of the stores department—a perpetual inventory of stores.

In some cases a "schedule" column is added

to the balance of stores sheet. As soon as a certain production is scheduled to be run, the quantity of material required for it is entered in this column. The use of a schedule column for materials regularly used in production will guard against over-ordering during a period of slack business or against loading up on materials which are gradually dropping out of use.

Whenever the store-room issues stores it must have a requisition, or "stores issue," for the amount. This "stores issue" is promptly forwarded to the "balance of stores" clerk to enter on his record. By this means each column of the "balance of stores" sheet is kept continuously balanced. The minimum quantity of material to keep in stock and the amount to order when the available stock reaches a minimum must be constantly watched and frequently revised to meet the changing conditions in the factory.

The balance of stores sheet, to be of value, must check with the stores actually on hand. This can be assured only by care in handling goods and records and in checking the records. Stores checkers should check each day a number of items with the balance sheets and bin tags. This is done by actual count. The items to be checked should be taken by some irregular plan that will give

Checking Materials

no notice in advance of what is to be checked while at the same time it will cover all materials at sufficiently frequent intervals.

This checking system should insure accuracy. It should show that the amount of material on hand is correctly recorded on the bin tag. The bin tag record must check with the balance sheet and the balance sheet must be correct with its entries and in its additions and subtractions. A careless balance clerk has been known to enter the date in the wrong column and add its numerals into the material quantity. The transposing of figures in copying is a common mistake, and must be carefully guarded against.

That the balance of stores sheets may be kept in agreement with the actual stores has been demonstrated again and again. In one plant the stock-room inventory made by actual count varied from the records only 0.01 per cent. When such control is maintained one may rely in confidence upon the balance of stores sheet for keeping materials on hand up to factory needs.

Requisitions

Almost anyone in the plant may be allowed to draw up a requisition, but it will be honored only if it has the OK of the proper official. Usually the foreman or other department head is the one who has the authority. It is advisable to

have all requisitions sent to stores. If they cannot be filled from stock the requisition will be numbered and its information noted on the stores sheet. One copy may then be returned to the requisitioner as notice that the order has been placed. The other copy will be sent to the purchasing agent. The purchasing agent in sending out his order usually incloses a return postal or detachable stub on the order, which may be used by the seller to notify him of the date of shipment. When this notification is received, it may be forwarded to the requisitioner. In this way the one requiring the material may be kept informed of the progress of his order.

A common fault in writing requisitions is to fail to give complete information regarding what is required. The man drawing the requisition may have a definite idea of what he wants and neglect to give these necessary details on paper. He fails to realize that others who are unfamiliar with his needs or conditions must either guess at the missing information or else return the requisition to have the details supplied. In many cases the store-keeper can supply the information to complete a requisition but such labors should not be expected of him. Every requisition should be complete and self-explanatory. To get materials promptly and satisfactorily let

your requisition leave nothing to the imagination or guesswork of the stores clerk.

The Foreman and the Handling of Stores

The cooperation of the foreman with his men in filling out requisitions and in scrupulous observance of all regulations regarding the withdrawal of material from the stores, is an important factor in plant efficiency. The minutes lost in correcting defective requisitions add up to an important item of wasted time in the course of a few months. Failure to observe the law of the stores department frequently causes loss in material, friction between employees, and other expensive irregularities. Such results can be avoided by thorough drilling of the men in these fundamentals.

This is a job which the farsighted foreman will rightly assume. He will first of all acquaint himself thoroughly with the details of stores management in his plant. He will learn its requisition system, its stores-keeping system, and he will post himself on the mistakes which are common to the workman in this connection. Then he will make himself a tactful instructor of all his men in these essential details. He will allow no faulty requisitions to get by him, but will immediately go to the workman responsible for the requisition, point out the mistake, explain the

reason for the rule, and thus make it almost impossible for that workman to fall into the same error again.

With such cooperation as this, stores management becomes of interest to every man in the factory team. The result is closer cooperation in utilizing materials, reduction of waste, and increase in output.

The foreman or other department head who masters this Unit should be better prepared to handle all departmental problems from the standpoint of the business as a whole. He may have nothing to do with store-keeping, no part at all in purchasing materials and supplies, and the choosing of machinery may be absolutely foreign to his duties. But knowledge of the principles which underlie store-keeping, purchasing, and the selection and care of equipment, and a clear understanding of why certain methods are followed and why specific rules are required, makes his work dovetail into the work of these other departments. He is able to cooperate more completely. Moreover, he is able to inspire his men with greater confidence and loyalty, and to get finer teamwork in his department.

QUIZ QUESTIONS

I

1. What three principles have made possible the big-scale, high-speed production of modern industry?

2. Why were the great inventions slow in making themselves felt in America?

3. What brought about the industrial awakening of the United States?

4. Name five products of which the United States is the leading producer.

5. What reason is given for the increasing use of machinery?

6. Why must the foreman know plant organization?

II

7. Name five ways of classifying manufacturing.

8. What nine groups of products are mentioned in the text, in classifying industries according to what they produce?

9. Mention two industries that make use of considerable hand labor. Mention two that are largely mechanical in their production.

10. Distinguish between chemical and physical manufacturing, and give illustrations of each.

11. What is parallel production? What is sequential production? Illustrate.

12. What is manufacturing to order? How does it differ from manufacturing for stock?

13. What advantages have been pointed out in favor of intermittent operation? What are the advantages of continuous operation?

III

14. What three elements constitute the production plant?

15. What four main questions affect plant location?

16. How do raw materials influence the location of the plant? Illustrate.

17. When does the pull of markets overweigh the pull of raw materials in determining the location of a plant?

18. How does labor supply affect location? What influence does the presence of transportation facilities have?

19. How does power supply affect location? How does climate affect location? Illustrate.

20. What are the advantages of a city location? What are the disadvantages?

21. What are the advantages of a country location? What are the disadvantages?

22. What are the advantages of a suburban location? What are the disadvantages?

23. Why is a steel mill usually built close to the ground? Why is a sugar refinery a tall structure of many stories?

24. What general type of building makes use of the saw-tooth roof, and what advantage is there in this kind of roof? What disadvantage?

25. What three advantages are there in a building of several stories?

26. How can an I type of building be made into one of the L type?

27. Mention four types of factory construction?

28. What is meant by plant equipment?

29. Mention three kinds of machinery.

30. What factors must be considered in determining how large to make the plant?

IV

31. What information is necessary to guide the laying out of a plant?

32. What is a process chart?

33. Why is rapid flow of work through the plant an advantage?

34. Why should the amount of work in process be kept as small as possible, commensurate with the intended output?

35. What is a pin plan and how is it made? How does it aid efficient placing of equipment?

36. How may work in process be stored pending its removal to the stock room?

37. Mention three plans for placing auxiliary equipment.

38. How may the source of power influence the plant layout? Under what condition is it possible to produce steam power very cheaply? What four questions affect the decision regarding power supply?

39. What four means of conveying may be employed in the factory?

40. Name three advantages of the gravity conveyor.

41. Under what conditions are traveling belts an advantage?

42. What is meant by plant layout in accordance with sequence? What is meant by plant layout in accordance with type of equipment? Under what conditions is each preferable?

43. What are the six fundamental rules in selecting machinery?

44. What is meant by capital efficiency as contrasted with machine efficiency?

45. How does labor supply affect choice of equipment?

46. Why is simplicity of mechanism an important consideration in selecting equipment?

47. When is a manufacturer warranted in having made-to-order machinery?

48. Under what circumstances is automatic machinery not an economy? What conditions make it a valuable factor in lowering costs?

49. Why is it usually cheaper in the long run to select machinery that is adjustable?

50. What different factors govern the speed of production?

51. What factor is usually the first consideration in manufacturing, though not one which determines the greatest earning power of the equipment?

52. How does power consumption affect the selection of equipment?

53. What is commonly meant by the term "tools"?

54. What should be the prime guide in the selection of tools?

55. What is a "go gauge"? A "no go gauge"?

56. What is tolerance, as the term is used in production?

57. What are jigs? What are fixtures?

VI

58. What attention is necessary in keeping the equipment fit?

59. Describe the essential features of the shop inspection system outlined in the text.

60. How are adjustments for wear made?

61. Why is it an advantage for the repair gang to have its own repair shop? How may the instruction-card plan be used in a repair system? Why are periodical overhaulings of all machinery an advantage?

62. What is meant by depreciation? How is it taken care of in the factory's accounting?

63. What is meant by obsolescence?

64. When is machine stripping justified? What plan is recommended to guard against its abuse?

65. Why is it important to keep careful record of the position of every piece of equipment?

66. What is the function of the tool-room? What is the function of the tool-cage?

67. What is the objection to the old practise of each workman grinding his own tools?

68. Into what two classes may tools be divided? In accounting for the expense of tools, how are the two classes charged on the records?

69. Describe the brass check system of keeping track of tools. Describe the double-check system.

VII

70. What is direct material? What is indirect material?

71. What two groups of material are called supplies?

72. Describe the best means of handling (a) bulky materials, (b) fluids in quantity, (c) heavy steel plates and shapes, (d) package materials.

73. Describe the method of calculating the minimum stock of material to carry.

74. How are patterns cared for, when the supplying of material involves the use of patterns furnished by the purchaser?

75. What is the advantage of having standard specifications for all materials?

76. What methods of safeguarding materials in storage are suggested?

77. How does speed affect the amount of spoiled work?

78. Describe the method of budgeting indirect materials.

VIII

79. What four steps are involved in making a purchase?

80. What sort of information should the purchasing agent be familiar with?

81. What is meant by centralized purchasing?

82. How does the position of purchasing agent in an industrial plant differ from that of buyer for a department store?

83. What are factors in deciding where to buy?

84. Into what three classes may purchases be grouped?

85. What is the routine in passing the invoice after goods are received?

86. What points must be considered in packing goods for shipment?

87. Why is it desirable to the manufacturer to ship f.o.b. rather than prepaid?

IX

88. What five subdivisions of the stores department are indicated in the text?

89. What are bins? What is meant by the double-bin system?

90. Why is regular turnover of stock desirable?

91. What advantages are there in the use of symbols for classifying and recording stores?

92. Explain the method of the Mnemonic system.

93. What is the function of the salvage department?

94. What is the balance of stores sheet?

95. Why is frequent checking of stores important?

96. What is a requisition?

97. What is the duty of the foreman with respect to the handling of stores?